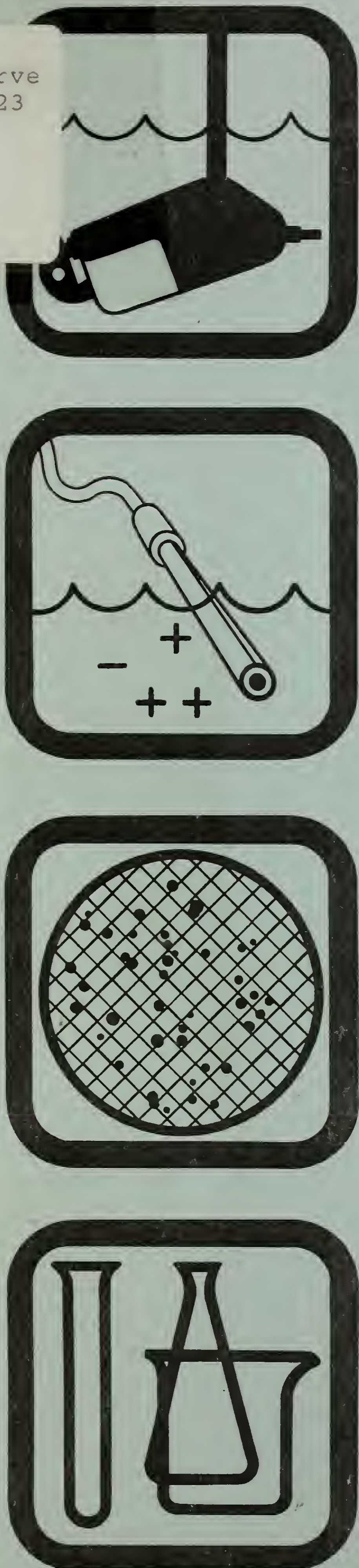

# TECHNICAL GUIDE

## FOR PREPARING WATER QUALITY MONITORING PLANS

**INTERMOUNTAIN REGION**
**Soil and Water Management**

# TECHNICAL GUIDE FOR PREPARING WATER QUALITY MONITORING PLANS

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## INTRODUCTION

Many legislative mandates require the Forest Service to take water quality into consideration in land management. The most well known legislation, Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972, established definite goals regarding restoration and maintenance of the physical, chemical, and biological integrity of the Nation's waters. In the Forest Service, water quality monitoring programs are utilized to characterize water quality and evaluate changes due to specific management activities. The intensity of monitoring depends on the intensity of resource management and potential for adversly effecting the environment and may concentrate on either long-term or short-term impacts. Water quality monitoring plans are the vehicle for documenting the process and methodology for acquiring water quality data necessary to meet these objectives. Plans must be carefully designed if logical conclusions and useful results are to be the final product.

Water quality is the term used to quantitatively describe composite physical, chemical, biological, and radiological characteristics of water with respect to its suitability for a particular use. Any discussion of water quality must consider not only the concentration of substances or organisms in the water, but also the uses that will be made of the water. This concept is central to the discussion of water quality.

## OBJECTIVE

The primary objective of this technical guide is to provide the hydrologist with a systematic procedure for preparing water quality monitoring plans so that pertinent and useful data are obtained with the least expenditure of time and money. While no uniform formula for the design of all monitoring plans exists, a number of fundamental principles are essential to all good plans. A rational thought process and logical stepwise sequence is presented to assist hydrologists in this task.

A secondary objective is to provide an overview of water quality monitoring strategies for National Forest System lands. The intent is to describe the current organizational and legislative framework pertinent to water quality management. An understanding of this background information is useful in establishing monitoring plans.

## OVERVIEW OF WATER QUALITY MANAGEMENT

Coordination of Forest Service water quality management with state and local agencies is essential. Congress, with the passage of the Clean Water Act, gave primary responsibility for water pollution control to states and required Federal agencies to comply with substantive and procedural state requirements. Subsequent legislation contained in Section 208 of the Federal Water Pollution Control Act Amendments, provided for the development of water quality management planning to control both point and nonpoint sources of pollution.

This planning is accomplished through state and areawide agencies working in cooperation with the Environmental Protection Agency and other affected Federal, state, and local agencies. The 208 planning process will result in state or areawide water quality management plans which will identify measures to reduce all sources of pollution. States have generally designated the Forest Service as the water quality management agency for National Forest System land, in recognition of the fact that the Forest Service is in the best position to implement water quality laws and regulations on National Forest lands.

The Forest Service has agreed to include water quality considerations in its land management planning process. Land management plans will set forth objectives for managing the quality of the water resource and contain guidelines and standards to be met in fulfilling these objectives. The Forest Plan, as identified in the National Forest Management Act (NFMA), will serve as the principle means through which state water quality management plans will be implemented and linked with National Forest lands.

The objective of the Forest Service is to provide and maintain water of a quality adequate for management and use of National Forest System resources and return it for downstream uses at a quality level which meets downstream use requirements. The Forest Service is concerned with monitoring both point and nonpoint sources of pollution. Point sources originate from a discrete identifiable source or conveyance and are generally regulated or controlled at their source. Direction for point source monitoring can be found in FSM 7430 and FSM 7440. Point sources are generally of minor significance on National Forest System lands in Region 4.

The major concern on National Forest lands has to do with nonpoint sources of pollution. Nonpoint sources result from natural processes, such as precipitation, seepage, percolation, and runoff, which are not traceable to any discrete or identifiable facility and which, because of their dispersed and sporatic nature, are not controllable by engineering facilities. For the most part, this guide addresses monitoring of nonpoint sources.

Nonpoint sources are controlled through the utilization of Best Management Practices (BMPs) as defined through the planning process established by Section 208 of the Federal Water Pollution Control Act Amendments. A Best Management Practice is a practice or combination of practices that is determined by a state (or designated area-wide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.

By agreeing to incorporate Section 208 water quality provisions in all future land use planning and management activities, the Forest Service has agreed to apply Best Management Practices to all activities on National Forest lands. The application of BMPs is a continuing process including identification of problems, devising control measures, assessing their adequacy, and modifying BMPs when necessary. States have the primary responsibility for evaluating

BMP effectiveness. The role of the Forest Service is to help states by evaluating selected management activities to determine how well water quality objectives are met and to incorporate timely and appropriate adjustments to those practices, where necessary, to ensure maintenance of water quality.

The BMP process and connecting links are illustrated in Figure 1. A twofold evaluation process is envisioned. One aspect consists of an interdisciplinary evaluation of BMPs. This concentrates on site specific evaluations of the operational application of BMPs and how well they were executed and implemented on the ground. This evaluation is applied to all activities. Results from the evaluation lead to modification of how BMPs are applied or modifications of BMPs themselves. The second aspect of BMP evaluation consists of traditional water quality and stream channel monitoring. This is done for selected management activities. Water quality monitoring plans discussed in this guide refer to monitoring to accomplish this aspect of BMP effectiveness evaluation. Information developed from water quality monitoring will be used to assess the effectiveness and need for revision of BMPs or changes in water quality goals if needed.

The Forest Service Manual defines water quality monitoring as "the systematic evaluation of achievement of water quality management goals, objectives, or targets." As a minimum, the Forest Service is legally required to conduct land management activities in such a manner that the water produced from National Forest lands meets state water quality standards. However, numerical water quality standards are generally recognized to only marginally apply to nonpoint sources. Consequently, until state standards are revised to more clearly reflect nonpoint source needs, they will not fully reflect the water quality goals and objectives of the Clean Water Act.

Water quality objectives are developed through Forest Service land management plans and should be contained in the Forest Plan. One suggested approach for including water quality objectives in the Forest plan is to develop "water quality goals" which would reflect the desired average quality of streams over a period of time. Implementing water quality goals would be a dramatic action demonstrating a positive attitude toward improving water quality management. For example, goals for selected water quality constituents could be developed with statistically stated means, confidence intervals, and levels of significance. Once established, means could be compared annually. An annual mean that violates water quality goals implies that, on the average, the stream and upland watershed has problems. The severity of the problem relates directly to the deviation of the mean from its goals and is an indicator of the success or failure of management activities within the watershed. Those streams not meeting water quality goals could be prioritized for increased management emphasis or watershed improvement work.

Water quality goals have the potential for greatly assisting the Forest Service in program planning, policy making, and public relations since the purpose of water quality goals is to assist in determining, through the use of water quality monitoring data, whether streams on National Forest lands meet our goals and expectations. Water quality goals are similar to stream water

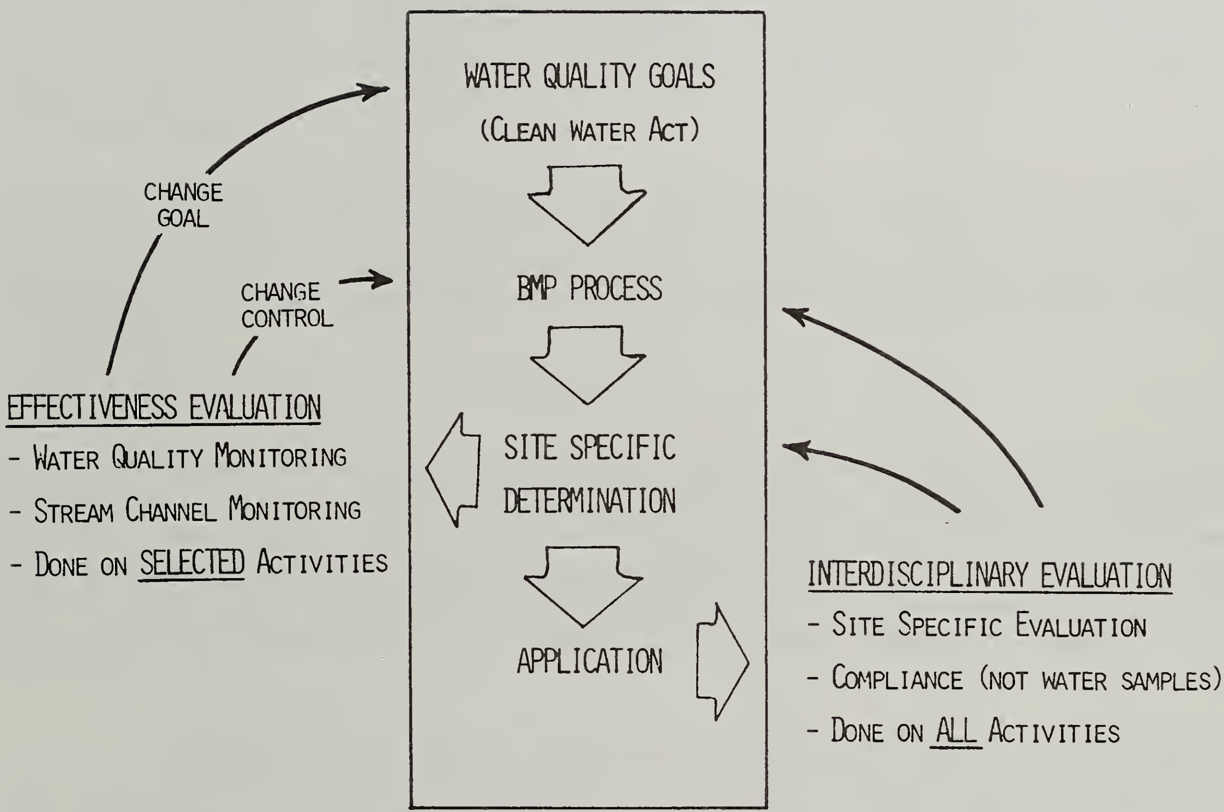


Figure 1. The BMP process.

quality standards but are based on an average of sample concentrations rather than having each sample serve to "spot check" whether quality thresholds, as defined by standards, have been violated.

Traditional water quality monitoring programs are poorly suited for detecting water quality threshold values which indicate a violation of standards. For example, assume that two samples out of 20 are in violation of standards. Is there really a problem, or are the samples quirks to be ignored within the realm of statistical probability? Interpretation of results is difficult since most monitoring programs, due to necessary economic restrictions on sampling frequency, are best suited for obtaining information about means in water quality. This does not imply that extremes in water quality are not important. We need to recognize, however, that fixed station, periodically sampled monitoring programs are not well suited for the purpose of detecting violations of stream standards. Water quality goals based on water quality means, on the other hand, or better suited to our sampling procedures and relay to land managers and the public the general trends in water quality in a more meaningful manner.

The above example, using water quality means, is an example of one type of water quality goal that could be incorporated into Forest planning. Other goals, such as maintaining a certain level of channel stability, riparian vegetative condition, macroinvertebrate population diversity, etc., could also be developed.

## TYPES OF MONITORING

Two major types of monitoring are recognized: (1) baseline monitoring and (2) project monitoring. One of the keys to an effective monitoring program is to integrate the types of monitoring so that they are complimentary. Information obtained from one type of monitoring can often serve more than one purpose. Some of each type of monitoring will generally be accomplished on all Forests. The exact mix of monitoring will vary to suit local management needs and concerns.

1. <u>Baseline Monitoring</u>. Baseline monitoring is done to characterize existing water quality conditions to establish a water quality data base for such purposes as planning, establishment of water quality goals, long-term trend assessment, or to address the adequacy of state water quality standards. Baseline monitoring is normally done on major streams at or near the Forest boundary. Initially, a broad spectrum of constituents may be measured, generally for a defined period of time, to characterize constituent variability. Once this is accomplished, monitoring intensity can be reduced in number of constituents sampled, station locations, or frequency of sampling, to the minimum necessary to meet ongoing objectives or resolve specific problems. Some amount of continuing baseline monitoring will always be needed to assess trends and/or attainment of water quality goals and standards. Baseline monitoring of water quality is one of the few available integrated indicators of the cumulative impacts resulting from multi-resource management.

2. Project Monitoring. The major purpose of project monitoring is to document the impacts of specific activities on water quality. Monitoring of this type can be designed to meet one or more of the following objectives: (1) compliance with state standards; (2) verify attainment of goals and objectives; (3) test and develop predictive techniques; and (4) measure effectiveness of BMPs. Project monitoring must include a representative sample of management activities occurring on the Forest to be responsive to Section 208 requirements.

Project monitoring is implemented to determine cause and effect relationships. Studies are designed to answer questions about what happened, why, and under what site and climatic conditions. It is generally short-term, lasting one to three years. Sampling is usually done in pairs with measurements taken above and below the activity; before, during, and after. A log of observations of on-site activities, climatic, and streamflow data are often collected concurrently to evaluate water quality impacts.

## COMPONENTS OF A WATER QUALITY MONITORING PLAN

The following stepwise process of preparing water quality monitoring plans is recommended. Many of the steps are closely linked and interdependent and should not be viewed as discrete, sequential steps. Some steps may be considered simultaneously, and it may be necessary to reconsider a step as additional information is developed. The process must be open, dynamic, and interactive to result in comprehensive plans. Every plan, as a minimum, should do the following:

1. Establish specific <u>objectives</u> relevant to management needs.

2. Assign <u>responsibility</u> for all phases of monitoring.

3. Review <u>existing data</u> available for the watershed of interest.

4. Establish data analysis <u>techniques and interpretations</u> to answer management needs.

5. Select water quality <u>constituents</u> which are relevant to water uses that are most likely to be affected by the management activity.

6. Select sampling <u>frequency</u> on the basis of statistical needs and hydrologically important characteristics.

7. Locate sample <u>stations</u> considering monitoring objectives.

8. Develop a timeframe for the <u>duration</u> of monitoring.

9. Describe field and laboratory <u>methodology</u>, including data storage, using currently accepted standard techniques.

10. Determine the <u>cost</u> of monitoring and adjust to meet budgetary constraints.

11. Determine the format for <u>report preparation</u> and schedule for publication of the results.

12. <u>Evaluate</u> on-going monitoring to assure that objectives are met.

## DEFINING MONITORING OBJECTIVES

The success or failure of a water quality monitoring plan is determined by how well monitoring objectives are defined. This is the first, the most important, and also the most difficult task to complete. Unless the objectives can be stated briefly and clearly, serious problems will rise in the other aspects of monitoring plan development. Objectives are nothing more than the specific questions which are to be answered by the monitoring. Give considerable thought to those questions since their answers will comprise a major portion of the plan.

The development of water quality monitoring objectives must evolve from the issues or concerns arising from the land manager's need for information to assist with decisionmaking. These needs must be identified by the line officer since water quality monitoring can only be justified if it is done to address specific needs of management for information. Commitment by management to monitoring programs is achieved through their involvement in setting objectives to answer pressing information needs.

Defining specific monitoring plan objectives is a joint effort between the hydrologist and the land manager. The hydrologist should take the lead in suggesting specific objectives which are technically feasible and satisfy the manager's needs. The hydrologist alone has the technical expertise and familiarity with water quality relationships to make this link. The manager has an equally important task of continually questioning and asking "why" to assure that the plan and its objectives speak only to identified needs. Involvement of other disciplines with an interest in water quality, such as fishery biologists, is often appropriate at this stage to coordinate common need for data. Interdisciplinary involvement can avoid duplication of effort and address a multitude of needs at one time.

Objectives should be as specific as possible to provide direction in developing the plan. General and/or all encompassing objectives should be avoided. As an example, consider the following objective: "Determine the effect of recreation activity in the wilderness area on surface water quality." This general objective should be made more specific by identifying such things as the kind of recreation use (day use, overnight camping, trail use), the exact location, the water bodies to be examined (lakes, streams, reservoirs), and the specific water quality characteristics (physical, biological, chemical) to be monitored. An example of the specific type of objective we should strive to develop is the following: "Determine the effect of overnight camping on the bacteriological quality of streams draining the West Fork drainages of the wilderness area." Specific objectives simplify the monitoring plan development process and are easier for the land manager to relate to and understand. The importance of establishing specific objectives cannot be overemphasized. It is the one technique most vital to the success and failure of any monitoring plan.

Objectives should be written down and agreed upon by line officers for several reasons. The act of putting them on paper requires careful thought and consideration of what the objectives should actually be. Written objectives also provide supervisors with the specialist's definition of the problem and give them a basis for judging the extent to which the proposed monitoring meets the needs that justified the undertaking. Written objectives are just plain good business. Not only do they provide evidence that the specialist is certain of his direction but they also provide the line officer with an understanding of what the specialist has proposed.

## ASSIGN RESPONSIBILITIES

Monitoring plans should clearly state who will be responsible for all phases of monitoring, including water sampling, laboratory analysis, data reduction,

analysis, interpretation, report writing, and plan evaluation. Responsible individuals should be identified by the specific position that will do the actual work and not merely by the organizational level responsible for accomplishment. Contracting should be considered when expertise is available, especially for such things as continuous streamflow gages, weather stations, and the collection of long-term water quality trend station data. The completed plan should be signed by the hydrologist, staff officer, and Forest Supervisor.

## REVIEW EXISTING DATA

Existing data about the quality and quantity of water within the drainage of interest should be reviewed prior to planning and drafting any water quality monitoring plan. Data should be analyzed in a very general way to provide direction for designing the plan. The use of existing data can save considerable time and money.

Many agencies and organizations collect water quality and quantity data. Two major sources of data are the U.S. Environmental Protection Agency's STORET data storage system and the U.S. Geological Survey's WATSTORE data storage system. Such data can provide valuable insight into stream variation and is, therefore, extremely useful in plan design. Information on concentration ranges and variability can be useful in determining sampling frequency, station location, and what characteristics to monitor. The data may identify some characteristics which normally might be overlooked. The search of existing data should not be limited to specific constituents of immediate interest but include other factors related to the functioning of the hydrologic system such as the degree, type, and intensity of management activities, stream channel and watershed condition, and releases from upstream impoundments.

## DATA ANALYSIS AND INTERPRETATION

The time to think about statistical analysis and interpretation of data is at the beginning of the study. The plan should spell out how the data will be analyzed, including specific analysis techniques, and address, in a general way, the interpretations that will be made from the data. All too often, little thought goes into how the data will be statistically analyzed and what hypotheses are to be tested until after it is collected.

Statistics has been defined as the mathematical science concerned with the methods and techniques of collecting, analyzing, and interpreting quantitative data in such a way that the reliability of conclusions can be evaluated objectively in terms of probability statements. While statistics has its place in sampling design and data analysis, there are some important limitations to its use. Statistical inference only provides a framework for expressing probability differences. It does not explain casual relations or reasons why something happens as it does. Where subjective analysis of water quality data may be questioned, statistics can be used to provide an objective basis for drawing conclusions. Statistics cannot and should not be used to

attempt to salvage poorly conceived monitoring programs. If you plan to use statistical techniques, it is essential that you consider statistical needs from the start and use statistically valid techniques.

Statistical considerations are instrumental in establishing sample frequencies, number of samples, and station locations. Man induced activities, such as road construction, logging, or recreation sites can cause water quality degradation of varying degrees. Certain natural background variables also affect water quality and may obscure the effects of the activities under investigation. It is, however, possible to design a monitoring plan to minimize the background effects if considered early in the development of the plan. Proper experimental design will help to control bias and will permit clearer estimation of the effects of selected activities. If natural variation is still so large that standard statistical methods, such as t-tests, cannot be used to detect differences, consider less powerful but, nevertheless, equally valid statistical tools such as non-parametric statistical tests.

Data interpretations must be considered from the beginning. Keep in mind during the entire plan development process exactly what it is that you are going to do with the data. Know how you are going to use the data in a manner that management can understand and which solves their problems. Interpretation is never an easy task. However, if the plan is well designed, logical conclusions and useful results will become evident from the data. Remember that interpretation is the task of transforming data into useful information and is much more important than the data itself.

Data analysis and interpretation is more than an excercise in mathematics. Mathematics and statistics are only tools used to assist in the formation of judgments and as such they may not be necessary in all studies. In some cases, depending on plan objectives, visual comparisons, water quality indices, and graphical presentations, such as stiff diagrams, may be all that is needed. In most instances, management relates to this type of data presentation better than to involved statistical analysis. Regardless of how data is presented, its significance must be demonstrated and clearly explained.

## SELECTION OF WATER QUALITY CONSTITUENTS

Selection of the water quality constituents to actually measure is the most technical phase in the development of a monitoring plan. It requires extensive knowledge of water quality characteristics, water quality interrelationships, and how they relate to the uses made of the water.

Two basic concepts should be kept in mind to guide constituent selection:

1. The relation of water quality constituents to the beneficial uses being made of the water under investigation.

2. The relation of water quality constituents to the objectives of the study, that is, the land management activity under investigation.

The beginning point for selecting constituents is to consider the beneficial uses that are made of the waters under investigation. Commonly considered uses include public water supply, agricultural irrigation, cold water fishery, wildlife and lifestock watering, primary and secondary contact recreation, stream and lake aesthetics, and industrial water supply. For each major use category, standards and criteria have been determined which not only identify the key constituents for each type of use but also set or recommend upper limits of allowable concentrations for each constituent to protect each use. These lists of constituents, derived from standards and/or criteria for various beneficial uses, provide a beginning point for constituent selection.

The essential difference between standards and criteria is that standards are established by authority. This fact, however, does not necessarily mean that they are fair or based on sound scientific knowledge. Standards are often established in response to outside influences, such as political expediency, or other factors, such as ease of measurement to facilitate administrative action or enforcement. Water quality standards are generally recognized to need improvement for application to nonpoint pollution sources, and, in many cases, standards have never been established for some of the constituents, such as sediment and bedload, of greatest interest to wildland conditions and forest management activities. Water quality criteria fill part of this gap by providing limits for some constituents not addressed by standards. Criteria are simply another yardstick against which to evaluate the quality of water. State water quality standards, however, take precedence over criteria since the Forest Service is legally bound to comply with them. Appendix A contains summary tables of water quality criteria for the major uses of water and a table of recommended criteria for each use. Readers are also referred to "Quality Criteria for Water," U.S. Environmental Protection Agency, July 1976, for additional detail on criteria and the rationale for their selection. Constituents identified in these lists can be used to supplement lists of constituents obtained from State standards to guide constituent selection. Appendix B contains summary information on state water quality standards for all the states in Region 4 (California, Idaho, Nevada, Utah, and Wyoming).

A final major consideration in constituent selection is to relate the constituents to the specific objectives of the monitoring plan. The constituents selected should normally be limited to those most likely to be significantly affected by the activity monitored. Consider the list of constituents identified based on standards and criteria and delete those constituents that will not be affected by the land management activity. Consider supplementing normal instream constituents with indices such as photo points, stream channel cross section measurements, macroinvertebrate sampling, intra-gravel sediment, etc., if appropriate, and include stream discharge since it is almost always needed to interpret any type of water quality data.

The greatest problem with constituent selection is the tendency to include constituents which are not really needed. Many studies include long lists of constituents which are merely nice to know or are included because they were studied elsewhere. Make every constituent selected for monitoring pay its way. Do not examine constituents just because they are easy to measure. Do not collect or measure something unless its relation to the hydrologic system and

the problem being studied can be justified. Beware of constituent grouping offered by laboratories as a matter of convenience. Excessive constituent selection results in the collection of a great many of the wrong kinds of data.

To guard against this problem, a short paragraph of each water quality constituent to be included in the monitoring program should be included in the plan. The rationale for including the constituent explains what the constituent reflects, relates it to the objectives, and explains what it is. This explanation serves two purposes; first, it provides the land manager with some insight into why the constituent was selected and describes its relationship to specific beneficial uses, land management activities, and other constituents; secondly, in writing the rationale, the specialist must reevaluate and justify to himself the reasons for monitoring each constituent. This process may cause him to seriously question the use of some constituents. The rationale has the added benefit of communicating to others involved with the monitoring, such as those who may be doing sample collection, preservation, and field analysis, what the study consists of and why it is done.

Appendix C contains a discussion of selected constituents and constituent groupings and their distribution in lakes and streams. The information contained in Appendix C can be used to prepare the rational for constituent selection and provides guidance for measuring many constituents. Additional references are provided for those needing more detailed information.

## SELECTION OF SAMPLING FREQUENCY

There are many factors to consider in establishing the frequency of sample collection. The specific objectives of the monitoring plan, the general hydrology, statistical validity, site accessibility, availability of funding, water quality constituents monitored, and personnel availability are some of the factors. The combination of these will be different for each plan and all of the factors are interrelated. The important thing in monitoring plan development is to consider all of them.

1. Seasonal hydrologic changes. Each year there will be high flow periods, low flow periods, and initial flushing periods. Since many water quality constituents are flow related, sampling as a minimum during high and low flows is often required. Other seasonal changes such as storm periods and their resultant runoff, rising and filling water temperatures, increased or decreased biological activity and so-forth should also be considered.

2. Influence of man-caused inputs. Man-caused inputs to the hydrologic system can produce profound changes in water quality and are often the focal point of our interest. Consequently, sampling frequency should consider the period of use or the time the activity takes place and sample accordingly. In many instances, maximum useful information can be obtained by sampling during or immediately after peak activity periods such as at swimming sites and for

recreational uses confined to certain times of the year (winter skiing, summer camping, weekend hiking). For other activities, man-caused inputs to the system may vary greatly in a random fashion and sample frequency must be increased to describe the distribution and abundance of water quality constituents with any reliability.

3. Types of constituents measured. Characteristics of the water quality constituents monitored must be considered in determining sampling frequency. Are the constituents flow related or not? Are they sorbed to solid particles? If, for example, you are interested in pesticides or trace metals, you may want to sample more frequently during periods of sediment transport. Some water quality constituents require special consideration because they change so rapidly. Examples are sediment (bedload, suspended, and turbidity measurements), temperature, and dissolved oxygen. Sediment is particularly sensitive to flow and also whether the hydrograph is rising or falling. Temperature and dissolved oxygen require a different sampling frequency because of their solar relationship. For example, to measure dissolved oxygen, you need to make night and day measurements because oxygen is strongly influenced by biological activity which is in turn influenced by light and darkness.

4. Statistical considerations - The ultimate goal of most monitoring is to compare values measured at a given site with those measured at another site (cause and effect) or at another time (baseline). To do this, something must be known about the variance of the constituents measured. If the natural variability of individual constituents is large, in order to increase the changes of detecting changes in water quality, a stratified sampling scheme should be used.

It is precisely because of expected sample variation, for example, that sampling during hydrologic events (high flows, low flows) is emphasized instead of a monthly or strictly time related schedule. The variability of sample measurements within a given hydrologic event is often less than the variability between events. This is significant for two reasons. First of all, valid comparisons between stations can only be made between stations for measurements made under similar hydrological events. Secondly, when using the hydrological event approach to guide frequency determination, as well as subsequent comparison of results, a stratified sampling scheme is automatically called for. Stratification can be based on factors other than seasonal flow regime, such as climate, geology, or channel morphology since all of these factors have a distinct influence on water quality and can be used to reduce variability. The important point to remember is that if you plan to use statistical evaluations of your data, you must employ statistical strategy in your sample collection and give full thought to the use of valid statistical methods at this time. As a general rule, a few locations with a sufficient number of samples to define results in terms of statistical significance are much more reliable than many stations with only a few samples at each.

A discussion of statistical sampling will not be provided here other than to point out that statistics can be used to calculate the frequency of sampling needed to detect change within stated confidence limits or to calculate the

minimum change which must take place before it can be detected by the sampling program. Details of these calculations can be found in most statistics texts.

5. Data interpretation - Always keep in mind that data interpretation is the end product of any data collection effort. Successful data interpretation ties directly to data collection. This means that when you decide to collect data at a given time, ask yourself how you will interpret that data for management.

Other considerations will also influence sampling frequency including budgetary constraints, travel distance to and between stations, available manpower, distance to laboratory facilities, sample preservation time, and many more. These factors can influence the frequency of sampling to the point where the validity of the study is compromised. In the event that nonhydrological constraints, such as budgets or manpower, force a reduction in sampling frequency, it is much better to restrict the area of study or the scope of the program than jeopardize the usefulness of the data.

In the determination of sampling frequency, the main purpose is always to define the period of interest considering all of the factors mentioned and then design sampling to characterize water quality only during that period. Sampling during the actual periods of interest rather than at a set frequency, according to the calendar, has advantages and disadvantages.

The primary advantage of sampling only during the period of interest is that the collection of data extraneous is largely eliminated. This reduces the possibility of comparing data having similar dates but which are not representative of similar hydrologic or use characteristics. Replicate sampling during the period of interest helps to reduce variation and permits more definite comparisons of data. The final advantage for sampling within specified periods is that it extracts the maximum amount of information out of a limited number of annual samples.

The primary disadvantages are administrative. This type of sampling requires flexibility in scheduling and continuous monitoring of the variables which define the period of interest such as flows, temperature, and use. Since these periods don't occur at the same time each year nor are they of equal duration, monitoring can be a problem. Access problems, unexpected flow changes, weather fluctuations, and the duration of these factors are but some of the things which make data collection, only during the period of interest, difficult. However, to reduce much of the background variability and make the best use of a limited number of samples, this type of sampling is strongly recommended.

## LOCATING SAMPLING STATIONS

The location of sampling stations requires the same attention to the needs and objectives of the monitoring plan as the other parts of the plan. Constituent selection, frequency of sampling, and station selection are intimately related and equally important, and therefore, cannot be evaluated separately.

Sampling station locations must be chosen with respect to the activities or uses being investigated. Each station, like the philosophy for selecting constituents, should pay its own way. If it does not, a great deal of time and money will be wasted traveling to unnecessary sites to collect unneeded data. While consideration of old data collection points and the location of existing stream gaging stations is important for continuity, it is more important to meet the needs and objectives of the monitoring plan than to locate stations for convenience.

Begin site selection by going back to the constituents to be monitored and select sites where representative samples of these constituents can be collected. It is important to select sites where samples can be obtained during both high and low flows. Consider not only the physical aspects of being able to collect a sample at high flow but also access to the site during winter months or storm conditions. Select sampling stations for accurate measurements and not primarily for convenience of sampling.

In many water quality monitoring plans, the primary strategy is to collect water samples above and below the activity or use of interest. The above station acts as a control and the below station is used to illustrate changes in water quality. While seemingly simple, this scheme is extremely useful. Care should be taken to see to it that the above station is a good control by considering such factors as mixing and tributary streams or groundwater entering the system between sample stations.

Sampling stations should be selected with some flexibility in the sampling scheduling. As previously stated, do not separate constituent types from the frequency of sampling and sampling station selection. This means that it may be useful to sample some constituents at different times of the year or at different sampling sites than other constituents. At a particular time of the year, the frequency of sampling a given constituent or the number of sampling sites may be reduced. A short narrative description of the specific location and an explanation of the reasons for its selection should be prepared for each station. Each monitoring station should be shown on appropriate maps which become part of the plan.

A data collection frequency matrix is a useful tool for summarizing and displaying the interrelationship between the constituents to be measured, the frequency of data collection, and the location of sampling stations. The data collection frequency matrix can be used as an easy reference as to what and when to sample or measure for both field and office personnel. A sample data collection frequency matrix is shown in Figure 2.

## DEVELOP TIMEFRAME

Water quality monitoring plans should establish a definite timeframe for the orderly completion of monitoring. This involves setting a timetable for summarizing the data, preparing a final report, and reviewing the plan itself. Open ended arrangements to collect data until "we have enough" or until an

Figure 2: DATA COLLECTION FREQUENCY MATRIX

| TYPE OF DATA | CONSTITUENTS | SAMPLING STATIONS | | | | | | 1st YEAR | | | | | | | | | | | | 2nd YEAR | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S |
| Discharge | | | | X | | | X | ---CONTINUOUS RECORD--- | | | | | | | | | | | | ---CONTINUOUS RECORD---- | | | | | | | | | | | |
| Discharge | Staff gage | X | X | X | X | X | X | --WITH EACH MEASUREMENT- | | | | | | | | | | | | -WITH EACH MEASUREMENT- | | | | | | | | | | | |
| Suspended Sediment | | | | X | | | X | -----DAILY OBSERVER---- | | | | | | | | | | | | -----DAILY OBSERVER----- | | | | | | | | | | | |
| Suspended Sediment | | X | X | | X | X | | 15 | 15 | 15 | 15 | 15 | 15 | 5<br>12<br>26 | 3<br>17<br>31 | 4<br>11<br>25 | 2<br>9 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 7<br>14<br>21 | 1<br>15<br>27 | 1<br>7<br>21 | 5<br>19 | 15 | 15 |
| Major Ions and Related Measurements | pH, Cond., Ca, Mg, Na, Cl, $SO_4$, TDS | X | X | X | X | X | X | 5<br>12<br>19 | | | | | | 8<br>15<br>22<br>29 | 4<br>11<br>18<br>25 | | 6<br>13<br>20 | | | 1<br>8<br>15 | | | | | | 1<br>7<br>21<br>28 | 3<br>10<br>17<br>24 | | 4<br>11<br>18 | | |
| Water Temperature | | | | X | | | X | --CONTINUOUS RECORD---- | | | | | | | | | | | | ---CONTINUOUS RECORD---- | | | | | | | | | | | |
| Plant Nutrients | $NO_3$, $PO_4$ | | | | X | X | X | | | | | | | 5<br>19 | 3<br>24 | 4<br>18 | 2<br>16 | 6<br>20 | | | | | | | | 1<br>15 | 7<br>21 | 5<br>19 | 3<br>17 | 5<br>14 | |
| Trace Metals | As, Cd, Co, Cr, Pb, Zn | X | X | X | | | | | | | | | | 1/15 | 1/15 | 1/15 | 1/15 | 1/15 | | | | | | | | 1/15 | 1/15 | 1/15 | 1/15 | 1/15 | |
| Dissolved Oxygen | Concentration & Saturation | | | X | | | X | ----DIEL ON 15th------- | | | | | | | | | | | | ---DIEL ON 15th-------- | | | | | | | | | | | |
| Benthic Invertebrate | Four, 1 sq. ft. samples | X | | X | | | X | 15 | | | | | | 15 | | | 15 | | | 15 | | | | | | 15 | | | 15 | | |

EXPLANATORY NOTES: 1/15 = on the 1st and 15th of each month
Diel = over a 24-hour period (6 am to 6 pm)

STATION LOCATIONS:
1 = at Highway 66 bridge
2 = at Longtree gage
3 = at Windsor gage
4 = at Arbuckle bridge
5 = at Williamsburg
6 = at mouth below Williamsburg

adequate baseline of data is established should be avoided. Determining the duration of the study should receive the same hard thought and scrutiny as the other aspects of the plan. When considered in terms of the specific objectives of the study, determination of a timeframe will generally be obvious since the amount of data needed and how it will be used has already been determined.

The development of a timeframe for the plan in general can be used as a tool to set time aside for data reduction, analysis, and establish deadlines for report preparation and data storage. In this way, the full time requirements of doing monitoring can be displayed to supervisors to clearly demonstrate that monitoring consists of more than the time required for data collection. Adequate time must be scheduled for data analysis, interpretation, and storage if we are to maximize the benefits of monitoring.

## METHODOLOGY

The monitoring plan must contain descriptions of field, laboratory, and data storage techniques to be followed in implementing the plan. This section should discuss methods of sampling, sample preservation, transportation of samples, sample analysis, and data handling. The guiding principle in methodology selection is to use the most modern approved state-of-the-art technique.

Two references are extremely useful to guide field and laboratory methodologies:

1. <u>The National Handbook of Recommended Methods for Water Data Acquisition</u> contains sections on water quality monitoring and is a joint effort cooperatively prepared by all government agencies with the U.S. Geological Survey as the lead agency.

2. <u>Standard Methods for the Examination of Water and Wastewater</u>, 13th Edition, contains recommended methods for laboratory analysis and is prepared and published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation.

The methods section should tell in detail how the monitoring plan is to be carried out. It should be complete enough so that anyone reading the plan, in the event the writer is no longer available, can follow the methods described. Where possible, methods should be referenced to one of the above publications by name and page number.

The methods section should also discuss the final disposition of the water quality data. The Environmental Protection Agency's STORET data storage and retrieval system for water quality is the generally accepted storage facility for Forest Service water quality data. Only high quality data, collected and analyzed by standard methods, should be placed on the system. Data should be summarized annually and put on STORET within one year of collection to assist with analysis and make it available to other users. Data that is not promptly

stored in a permanent systematic manner is often lost as personnel changes occur and investments made to obtain the data is often needlessly wasted. Decisions to accummulate data "until I have some extra time to store it" are misguided since time for those nonpriority jobs never seems to materialize. If the data is important enough to collect, it should be important enough to permanently store for future use.

The following convention is recommended for Region 4 primary station codes used in STORET:

| | | |
|---|---|---|
| FOREST | Required | (2 digits from Regional code for Forest) |
| DISTRICT | Required | (2 digits from Forest code for Districts) |
| NFS WATERSHED | Optional | (3 digit code from FSM 2573.5 R-4 Supp. 50) |
| OTHER | Optional | (up to 8 spaces available) |

The Region 4 agency code is 113FORS4.

## COST DETERMINATION

During the initial development stage of the monitoring plan, no dollar constraints should be imposed so that the most technically sound plan is designed. If subsequent choices must be made concerning plan revision, due to budgetary constraints, a wide spectrum of alternatives will be available.

The costs of water quality monitoring include:

1. Laboratory expenses.
2. Man hours for sample collection, streamflow measurements, and field determinations.
3. Travel costs.
4. Purchase of additional equipment if needed.
5. Computer data storage costs (if necessary).
6. Man hours for analysis, evaluation, and reorganization of the plan, if needed.

Costs of these activities can vary considerably. In all cases, available dollars must be compared with the costs of implementing the plan.

Generally, slight changes in constituents, frequency of sampling, or the number of stations will reduce monitoring costs to acceptable levels. The manager, however, must be made aware of how these changes affect the attainment of plan objectives. If the changes are so severe that they seriously hamper the attainment of objectives, monitoring should either not be initiated or additional funds must be requested. It is important not to continue with a plan which has been so compromised by constraints that meaningful data can no longer be obtained. If this is the case, the concerns of the specialist must be communicated to the manager so the impact of any decisions to curtail the plan are clearly understood.

Water quality monitoring plans are expensive and dollars will always influence this activity. It is important for the manager to see how the money is spent

and how that expenditure helps in the attainment of management goals. We can no longer afford to collect data for its own sake. The time is fast approaching when we will be held accountable for how well water quality dollars are spent to answer management's needs for information.

## REPORT PREPARATION

The important point about the monitoring report is to see to it that it actually gets written. Every monitoring plan that is worth implementing in the first place is worth reporting. A decision to file the data "until there is time to write the report" is generally fatal. Files are crowded with data that was never analyzed because the time to write the report never came. Anyone who has had occasion to attempt to salvage data two, five, or ten years old realizes the difficulties attendent with making any sense out of it. Reports must be prepared as soon as possible after completion, preferably by the individual who prepared the plan, while the details of the study are still fresh. Provisions and scheduling of timely report preparation, as well as assigning responsibility for preparing the report, must be made a part of the plan. In some cases, only a final report will be necessary while, in others, annual progress reports or summaries may be appropriate to stay current with data summarization and storage needs and to keep supervisors posted of progress.

The actual format of the reports will depend on the objectives and scope of the study and is left to the discretion of the Forest. Many of the components of the monitoring plan can be incorporated in the final report if necessary. Determine who the audience is for any given report and write to their level of technical expertise. This often means that technical language and detail must be defined or explained so the layman can understand them. Do not simply portray data using numbers, graphs, tables, or charts. The goal of the report is to transform data into information. The essential thing is to tie all the results together and tell the reader what the numbers mean.

## MONITORING EVALUATION

The design of monitoring plans should not be considered finished once the plan is implemented. Changes may be required in constituents, sampling frequency, or station locations. Continuous review of data, as it is collected, may suggest problems not foreseen in the developmental stage.

Similarly, budgets and laboratory capabilities may change and require plan revision. For these reasons, monitoring plans should be reviewed annually to see that objectives are being met. When changes are indicated, they should be made taking care not to alter techniques and methods to such a degree that data useability is compromised. All revisions of the plan should be fully documented. The schedule for periodic plan review and possible revision should be made a part of the plan to assure accomplishment.

Water quality monitoring plans, in general, need to be evaluated over the long term to provide continued improvement of existing as well as future,

monitoring. The analysis and interpretation of data and how well it satisfies management needs is the best evaluation of a water quality program. Mistakes and past experience can form a solid basis for preparing sounder monitoring plans in the future. However, we must take the time to discover and analyze our mistakes and successes to profit from this experience.

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# APPENDIX A:

# WATER QUALITY CRITERIA

A broad range of criteria, from a range of sources, are presented to create an awareness of the diversity of thought prevalent in the scientific community concerning the validity of the criteria. A table of recommended criteria is provided as a synthesis of the most commonly accepted criteria values.

Source: CH2M Hill. 1976. Interim Clean Water Report for Southwestern Wyoming. Prepared for Southwestern Wyoming Water Quality Planning Assoc., December 1976, Section 2.

RECOMMENDED WATER QUALITY EVALUATION CRITERIA
(All units in mg/l except as noted)

| Parameter | Secondary Contact Recreation | Primary Contact Recreation | Stream and Lake Aesthetics | Power Plant Cooling | Industrial Water Supply | Agricultural Irrigation | Wildlife and Livestock Watering | Public Water Supply | Cold Water Fishery |
|---|---|---|---|---|---|---|---|---|---|
| Alkalinity | - | - | - | 150 | 500 | - | 30-130 | - | 20 minimum |
| Aluminum | - | - | - | 0.1 | - | 5.0 | 5.0 | - | 0.100 |
| Aquatic Growth | Virtually free[1] | Virtually free[1] | Virtually free[1] | - | - | - | No blue-green algae | - | - |
| Arsenic | - | - | - | - | - | 0.10 | 0.2 | 0.05 | 0.05 |
| Bacteria | | | | | | | | | |
| Fecal Coliform | 1,000/100ml[3] | 200/100ml[2] | - | - | - | 1,000/100ml | - | 2,000/100ml | - |
| Total Coliform | - | - | - | - | - | - | - | 10,000/100ml | - |
| Barium | - | - | - | - | - | - | - | 1.0 | 5.0 |
| Beryllium | - | - | - | - | - | 0.10 | - | - | 0.011-1.1[8] |
| Bicarbonate | - | - | - | 140 | 480 | - | - | - | - |
| Boron | - | - | - | - | - | 0.75 | 5.0 | 0.75 | - |
| Cadmium | - | - | - | - | - | 0.01 | 0.050 | 0.010 | 0.0004-0.015[8] |
| Calcium | - | - | - | 420 | 220 | - | - | - | - |
| Chloride | - | - | - | 20,000 | 1,600 | 100 | - | 250 | - |
| Chlorine | - | - | - | - | - | - | - | - | 0.003 |
| Chromium | - | - | - | - | - | 0.10 | 0.05 | 0.050 | 0.05 |
| Cobalt | - | - | - | - | - | 0.05 | 1.0 | - | - |
| Color | - | Virtually free[1] | Virtually free[1] | - | 25 units[5] | - | - | 75 units[5] | - |
| Copper | - | - | - | - | - | 0.2 | 0.5 | 1.0 | 0.010-0.040[8] |
| Cyanide | - | - | - | - | - | - | - | 0.2 | 0.005 |
| Floating Debris and Scum | Virtually free[1] | Virtually free[1] | Virtually free[1] | - | - | - | - | - | - |
| Fluoride | - | - | - | - | 1.2 | 1.0 | 2.0 | 1.8[6] | - |
| Hardness | - | - | - | 7,000 | 900 | - | - | - | - |
| Iron | - | - | - | 0.5 | 13 | 5.0 | - | 0.3 | 0.5 |
| Lead | - | - | - | - | - | 5.0 | 0.1 | 0.05 | 0.004-0.150[8] |
| Lithium | - | - | - | - | - | 2.5 | - | - | - |
| Magnesium | - | - | - | - | 85 | - | - | - | - |
| Manganese | - | - | - | 0.5 | - | 0.2 | - | 0.05 | 1.0 |
| Mercury | - | - | - | - | - | - | 0.0005 | 0.002 | 0.00005 |
| Nickel | - | - | - | - | - | 0.20 | - | - | 0.050-0.400[8] |
| Nitrogen | | | | | | | | | |
| Ammonia ($NH_3$-N) | - | - | - | - | 33 | - | - | 0.5 | 0.020 un-ionized |
| Nitrate ($NO_3$-N) | - | - | - | - | 2 | - | - | 10.0 | - |
| Nitrite ($NO_2$-N) | - | - | - | - | - | - | 10 | 1.0 | - |
| Nitrite + Nitrate | - | - | - | - | - | - | 100 | - | - |
| Odor (Objectionable) | Virtually free[1] | Virtually free[1] | Virtually free[1] | - | - | - | - | Virtually free[1] | - |
| Oil | Virtually free[1] | Virtually free[1] | Virtually free[1] | - | - | - | No visible floating | Virtually free[1] | No visible floating |
| Organics | | | | | | | | | |
| Carbon Chloroform Extract | - | - | - | - | - | - | - | 0.7 | - |
| Chlorophyll a | - | - | 0-4 mg/m$^3$ | - | - | - | - | - | - |
| Polychlorinated Biphenyls (PCB) | - | - | - | - | - | - | - | 0.001 | 0.000001 |
| Oxygen, Dissolved | - | - | - | - | - | - | Aerobic | - | 4.0-9.3[9][10] |
| pH | - | 6.5-8.3 | - | 5.0-8.4 | 6.0-9.0 | 4.5-9.0 | 7.0-9.2 | 5.0-9.0 | 6.5-9.0 |
| Phenols | - | - | - | - | - | - | - | 0.001 | 0.001 |
| Phosphate (Total) | - | - | 0.05[4] | 5 | - | - | - | - | - |
| Selenium | - | - | - | - | - | 0.020 | 0.05 | 0.010 | 0.050 |
| Silica | - | - | - | 25 | 50 | - | - | - | - |
| Silver | - | - | - | - | - | - | - | 0.05 | 0.00010-0.00025[8] |
| Solids | | | | | | | | | |
| Settleable | - | Virtually free[1] | Virtually free[1] | - | - | - | Minimized | - | - |
| Suspended | - | - | - | 250 | 5,000 | - | - | - | 80 |
| Total Dissolved | - | - | - | 35,000 | 3,500 | 2,000 | 3,000[7] | 500 | 2,000 |
| Sulfate | - | - | - | 2,700 | 570 | 200 | - | 250 | - |
| Sulfide | - | - | - | 4 $H_2S$ | 20 $H_2S$ | - | - | - | 0.002 undissociated $H_2S$ |
| Temperature | | | | | | | | | |
| Minimum | - | 15°C (59°F) | - | - | - | - | Avoid changes in freezing dates | - | - |
| Maximum | - | 35°C (94°F) | - | 49°C (120°F) | - | - | - | - | 18.2°C (64.8°F) |
| Vanadium | - | - | - | - | - | 0.10 | 0.1 | - | - |
| Zinc | - | - | - | - | - | 2.0 | 25.0 | 5.0 | 0.050-0.060[8] |

(1) Virtually free is used to imply freedom from the undesirable effects of the constituent itself. This recognizes the practical impossibility of complete absence and the inevitability of the presence of potential pollutants to some degree.
(2) Log mean of a minimum of five samples taken over 30 days. Ten percent of the total samples for any 30-day period shall not exceed 400/100ml.
(3) Log mean of a minimum of five samples taken over 30 days. Ten percent of the total samples for any 30-day period shall not exceed 2,000/100ml.
(4) Suggested standard for streams. Suggested standard for lakes is 0.025 mg/l.
(5) Platinum-cobalt units.
(6) Based on the average annual maximum daily air temperature of 18.6°C (65.5°F).
(7) As close to natural conditions as possible. Rapid fluctuations should be minimized.
(8) Value dependent on the hardness as shown by Davies and Goettl, July 1976.
(9) See Figure 3.
(10) For streams which have low dissolved oxygen levels due to pollution, a minimum value is 5 mg/l.

PUBLIC WATER SUPPLY

SUMMARY OF WATER QUALITY CRITERIA (all units in mg/l except as noted)

| Parameter | National Academy of Science, 1972[1] | McKee and Wolf, 1963[2] | EPA, Oct. 1973a | HEW, 1962[2] | AWWA Dec. 1, 1971[2] | EPA, Dec. 24, 1975[2] | EPA, Mar. 14, 1975[2] | EPA, Oct. 10, 1975[1] | Recommended Water Quality Evaluation Criteria[1] |
|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 0.1 | 0.05 | 0.1 | 0.01 | - | 0.05 | 0.05 | 0.05 | 0.05 |
| Bacteria | | | | | | | | | |
| Fecal Coliform | 2,000/100ml | - | 2,000/100ml | - | - | - | - | - | 2,000/100ml |
| Total Coliform | 20,000/100ml | - | 10,000/100ml | 4/100ml | - | 1/100ml | - | - | 10,000/100ml |
| Barium | 1.0 | 1.0 | 1.0 | - | - | 1.0 | 1.0 | 1.0 | 1.0 |
| Boron | 0.75 | - | 1.0 | - | - | - | - | 0.75 | 0.75 |
| Cadmium | 0.010 | - | 0.01 | - | - | 0.010 | 0.010 | 0.010 | 0.010 |
| Chloride | 250 | 250 | 250 | 250 | - | - | - | 250 | 250 |
| Chromium | 0.05 | 0.05 | 0.05 | - | - | 0.05 | 0.05 | 0.050 | 0.050 |
| Color | 75 units[3] | - | 75 units[3] | 15 units[3] | 3 units[3] | - | - | 75 units[3] | 75 units[3] |
| Copper | 1.0 | 1.0 | 1.0 | 1 | 0.5 | - | - | 1.0 | 1.0 |
| Cyanide | 0.2 | - | 0.2 | 0.01 | - | - | 0.2 | 0.2 | 0.2 |
| Fluoride | 1.4-2.4[2] | 0.7-1.2 | - | - | - | (4) | 1.4-2.4[5] | - | 1.4-2.4[5] |
| Iron | 0.3 | 0.3 | 0.3 | 0.3 | 0.05 | - | - | 0.3 | 0.3 |
| Lead | 0.05 | 0.1 | 0.05 | - | - | 0.05 | 0.05 | 0.05 | 0.05 |
| Manganese | 0.05 | 0.05 | 0.05 | 0.05 | - | - | - | 0.050 | 0.05 |
| Mercury | 0.002 | - | 0.002 | - | - | 0.002 | 0.002 | 0.002 | 0.002 |
| Nitrogen | | | | | | | | | |
| Ammonia | 0.5 | - | 0.5 | - | - | - | - | - | 0.5 |
| Nitrate ($NO_3$-N) | 10 | - | 10 | 10 | - | 10 | 10 | 10 | 10.0 |
| Nitrite ($NO_2$-N) | 1 | - | 1.0 | - | - | - | - | - | 1.0 |
| Odor (Objectionable) | Virtually free[6] | - | Free from | - | Free from | - | - | Free from | Virtually free[6] |
| Oil | Virtually free[6] | - | Free from | - | - | - | - | Free from | Virtually free[6] |
| Organics | | | | | | | | | |
| Carbon Chloroform Extract | - | - | - | 0.2 | - | 0.07 | 0.7 | - | 0.7 |
| Polychlorinated Biphenyls | - | - | - | - | - | - | - | 0.001 | 0.001 |
| pH | 5.0-9.0 | - | 5.0-9.0 | - | - | - | - | 5.0-9.0 | 5.0-9.0 |
| Phenolic Compounds | 0.001 | 0.001 | 0.001 | 0.001 | - | - | - | 0.001 | 0.001 |
| Selenium | 0.01 | - | 0.01 | - | - | 0.01 | 0.01 | 0.010 | 0.010 |
| Silver | 0.001 | - | 0.05 | - | - | 0.05 | 0.05 | 0.050 | 0.05 |
| Solids | | | | | | | | | |
| Total Dissolved | - | 1,000 | - | 500 | - | - | - | - | 500 |
| Sulfate | 250 | 500 | 250 | 250 | - | - | - | 250 | 250 |
| Zinc | 5 | - | 5.0 | 5.0 | 5.0 | - | - | 5.0 | 5.0 |

(1) Assume water treatment--quality is for raw water before treatment.
(2) Treated water.
(3) Platinum-cobalt units.
(4) Dependent on temperature.

| *Annual Average of Maximum Daily Air Temperatures, °F* | *Recommended Control Limits of Fluoride Concentrations, mg/l* Lower | Optimum | Upper |
|---|---|---|---|
| 50.0-53.7 | 0.9 | 1.2 | 1.7 |
| 53.8-58.3 | 0.8 | 1.1 | 1.5 |
| 58.4-63.8 | 0.8 | 1.0 | 1.3 |
| 63.9-70.6 | 0.7 | 0.9 | 1.2 |
| 70.7-79.2 | 0.7 | 0.8 | 1.0 |
| 79.3-90.5 | 0.6 | 0.7 | 0.8 |

(5) Dependent on temperature.

| *Annual Average of Maximum Daily Air Temperatures, °F** | *Fluoride Maximum, mg/l* |
|---|---|
| 80-91 | 1.4 |
| 72-79 | 1.6 |
| 65-71 | 1.8 |
| 59-64 | 2.0 |
| 55-58 | 2.2 |
| 50-54 | 2.4 |

* Based on temperature data obtained for a minimum of 5 years.

(6) Virtually free is used to imply freedom from the undesirable effects of the constituent itself. This recognizes the practical impossibility of complete absence and the inevitability of the presence of potential pollutants to some degree.

WILDLIFE AND LIVESTOCK WATERING
SUMMARY OF WATER QUALITY CRITERIA (all units in mg/l except as noted)

| Parameter | National Academy of Science, 1972 | National Technical Advisory Committee, April 1, 1968 | Recommended Water Quality Evaluation Criteria |
|---|---|---|---|
| Alkalinity | 30-130 (1) | 35-200 (1) | 30-130 (1) |
| Aluminum | 5.0 | - | 5.0 |
| Aquatic Growth | No blue-green algae | Avoid abnormal growth of blue-green algae | No blue-green algae |
| Arsenic | 0.2 | 0.05 | 0.2 |
| Boron | 5.0 | - | 5.0 |
| Cadmium | 0.050 | 0.01 | 0.050 |
| Chromium | 1.0 | 0.05 | 0.05 |
| Cobalt | 1.0 | - | 1.0 |
| Copper | 0.5 | - | 0.5 |
| Fluoride | 2.0 | 2.4 | 2.0 |
| Lead | 0.1 | 0.05 | 0.1 |
| Mercury | 0.0005 | - | 0.0005 |
| Nitrogen | | | |
| Nitrite ($NO_3$-N) | 10 | - | 10 |
| Nitrite + Nitrate | 100 | - | 100 |
| Oil | No visible floating (3) | Excluded (3) | No visible floating (3) |
| Oxygen, Dissolved | - | Aerobic (3) | Aerobic (3) |
| pH | 7.0-9.2 (3) | 7.0-9.2 (3) | 7.0-9.2 (3) |
| Selenium | 0.05 | 0.01 | 0.05 |
| Solids | | | |
| Settleable | Minimized (3) | Excluded (3) | Minimized (3) |
| Total Dissolved | 3,000 (4) | 10,000 (2) | 3,000 (4) |
| Temperature | Avoid changes in freezing dates | - | Avoid changes in freezing dates |
| Vanadium | 0.1 | - | 0.1 |
| Zinc | 25.0 | - | 25.0 |

(1) Fluctuations should be less than 50 mg/l.
(2) "Salinity should be as close to natural conditions as possible." Natural salinity is assumed to be less than 500 mg/l with an allowable fluctuation of 1 percent in salinity content 10,000. 10,000 is also the maximum limit for livestock watering.
(3) For the protection of waterfowl.
(4) As close to natural conditions as possible. Rapid fluctuations should be minimized.

COLD WATER FISHERY

SUMMARY OF WATER QUALITY CRITERIA (all units in mg/l except as noted)

| Parameters | National Academy of Science, 1972 | McKee and Wolf, 1963 | EPA, Oct. 10, 1975 | Davies & Goettl, July 1976 | Recommended Water Quality Evaluation Criteria |
|---|---|---|---|---|---|
| Alkalinity | - | - | 20 minimum | - | 20 minimum |
| Aluminum | - | - | - | 0.100 | 0.100 |
| Arsenic | - | 1.0 | - | 0.05 | 0.05 |
| Barium | - | 5.0 | - | - | 5.0 |
| Beryllium | - | - | 0.011 soft water,[2] 1.10 hard water[3] | 0.011[9] 0.300[10] 0.600[11] 0.900[12] 1.100[13] | 0.011-1.1[14] |
| Cadmium | 0.004[2] 0.03[3] | - | 0.0004[2] 0.003[3] | 0.0004[9] 0.001[10] 0.005[11] 0.010[12] 0.015[13] | 0.0004-0.015[14] |
| Chlorine | 0.003 | - | 0.003 | - | 0.003 |
| Chromium | 0.05 | 0.05 | 0.30 | 0.3 | 0.05 |
| Copper | (4) | 0.02 | (4) | 0.010[9] 0.010[10] 0.010[11] 0.020[12] 0.040[13] | 0.010-0.040[14] |
| Cyanide | 0.005 | - | 0.005 | 0.005 | 0.005 |
| Iron | - | - | 1.0 | 0.5 | 0.5 |
| Lead | 0.03 | 0.1 | (6) | 0.004[9] 0.025[10] 0.050[11] 0.100[12] 0.150[13] | 0.004-0.150[14] |
| Manganese | - | 1.0 | - | 1.0 | 1.0 |
| Mercury | 0.00005 | - | 0.00005 | 0.00005 | 0.00005 |
| Nickel | (5) | - | 0.100 | 0.050[9] 0.100[10] 0.200[11] 0.300[12] 0.400[13] | 0.050-0.400[14] |
| Nitrogen | | | | | |
| Ammonia | using un-ionized $NH_3$ (1) | - | 0.020 un-ionized ammonia | 0.020 un-ionized | 0.020 un-ionized |
| Oil and Grease | No visible surface and (1) | - | (6) | - | No visible floating |
| Organics | | | | | |
| Polychlorinated Biphenyls | 0.000002 | - | 0.000001 | - | 0.000001 |
| Oxygen, Dissolved | - | 3-5 | 4.0-9.3[8] | - | 4.0-9.3[8] |
| pH | 6.5-8.5 max Δ=0.5 | - | 6.5-9.0 | - | 6.5-9.0 |
| Phenols | 0.1 | 0.2 | 0.001 | - | 0.001 |
| Selenium | - | - | (6) | 0.050 | 0.050 |
| Silver | - | - | (6) | 0.00010[9] 0.00010[10] 0.00015[11] 0.00020[12] 0.00025[13] | 0.00010-0.00025[14] |
| Solids | | | | | |
| Suspended | high level protection-25 moderate-80 low-400 | - | excellent-25 good-80 fair-400 | - | 80 |
| Total Dissolved | - | 2,000 | - | - | 2,000 |
| Sulfide | 0.002 undissociated $H_2S$ | - | 0.002 undissociated $H_2S$ | 0.002 undissociated $H_2S$ | 0.002 undissociated $H_2S$ |
| Temperature | 18.2°C (64.8°F) | - | - | - | 18.2°C (64.8°F) |
| Zinc | (7) | - | (6) | 0.050[9] 0.050[10] 0.100[11] 0.300[12] 0.600[13] | 0.050-0.60[14] |

(1) To be based on 0.05 times the 96-hour LC50.
(2) Soft water, hardness less than 100 mg/l $CaCO_3$.
(3) Hard water, hardness greater than 100 mg/l $CaCO_3$.
(4) To be based on 0.1 times the 96-hour LC50 using sensitive aquatic resident species.
(5) To be based on 0.02 times the 96-hour LC50.
(6) To be based on 0.01 times the 96-hour LC50 using sensitive aquatic resident species.
(7) To be based on 0.005 times the 96-hour LC50.
(8) See Figure 12. For streams which have low dissolved oxygen levels due to pollution, a minimum value is 5 mg/l.
(9) Hardness between 0-100.
(10) Hardness between 100-200.
(11) Hardness between 200-300.
(12) Hardness between 300-400.
(13) Hardness greater than 400.
(14) Value dependent on the hardness as shown by Davies and Goettl, July 1976.

AGRICULTURAL IRRIGATION

SUMMARY OF WATER QUALITY CRITERIA (all units in mg/l except as noted)

| Parameter | National Academy of Science, 1972 | McKee and Wolf, 1963 | EPA, Oct. 10, 1975 | University of California, 1976 | Recommended Water Quality Evaluation Criteria |
|---|---|---|---|---|---|
| Aluminum | 5.0 | - | - | 5.0 | 5.0 |
| Arsenic | 0.10 | 1.0 | 0.100 | 0.1 | 0.10 |
| Bacteria | | | | | |
| Fecal Coliform | 1,000/100ml | - | - | - | 1,000/100ml |
| Beryllium | 0.10 | - | 0.100 | 0.1 | 0.10 |
| Boron | 0.75 | 0.67-1.0 (2) | 0.75 | 0.75 | 0.75 |
| Cadmium | 0.010 | - | - | 0.01 | 0.01 |
| Chloride | - | 100 | - | - | 100 |
| Chromium | 0.10 | - | - | 0.1 | 0.10 |
| Cobalt | 0.050 | - | - | 0.05 | 0.05 |
| Copper | 0.2 | - | - | - | 0.2 |
| Fluoride | 1.0 | 10.0 | - | 1.0 | 1.0 |
| Iron | 5.0 | - | - | 5.0 | 5.0 |
| Lead | 5.0 | - | - | 5.0 | 5.0 |
| Lithium | 2.5 | - | - | 2.5 | 2.5 |
| Manganese | 0.20 | 0.50 | - | 0.2 | 0.2 |
| Molybdenum | 0.010 | - | - | 0.01 | 0.01 |
| Nickel | 0.20 | - | 0.100 | 0.20 | 0.20 |
| pH | 4.5-9.0 | - | - | - | 4.5-9.0 |
| Phenols | - | 50 | - | - | 50 |
| Selenium | 0.020 | - | - | 0.02 | 0.020 |
| SAR | 4 to 8 may injure sodium sensitive plants | - | - | - | - |
| Solids | | | | | |
| Total Dissolved | 2,500 (1) | 700 | 2,000 (3) | - | 2,000 |
| Sulfate | - | 200 | - | - | 200 |
| Vanadium | 0.10 | - | - | 0.10 | 0.10 |
| Zinc | 2.0 | - | - | 2.0 | 2.0 |

(1) Dependent on crop salt tolerance. 2,500 is a median value for crops with a moderate salt tolerance.

(2) Permissible level for sensitive crops.

(3) Not a recommended value. Number is based on National Technical Advisory Committee to Secretary of Interior, 1968. Limit for water that may have adverse effects on many crops and requires careful management practices.

PRIMARY CONTACT RECREATION
SUMMARY OF WATER QUALITY CRITERIA (all units in mg/l except as noted)

| Parameter | National Academy of Science, 1972 | McKee and Wolf, 1963 | EPA, Oct. 10, 1975 | National Technical Advisory Committee, April 1, 1968 | Recommended Water Quality Evaluation Criteria |
|---|---|---|---|---|---|
| Aquatic Growth (substances and conditions which produce undesirable aquatic growth) | Virtually free (1) | - | Free from (3) | Free from | Virtually free (1) |
| Bacteria | | | | | |
| Fecal Coliform | No specific recommendation | No specific recommendation | 200/100ml (2) | 200/100ml (2) | 200/100ml (2) |
| Clarity (Secchi Disc Depth) | - | - | - | 4 ft. | - |
| Color (Objectionable) | Virtually free (1) | - | Free from (3) | Free from | Virtually free (1) |
| Floating Debris and Scum | Virtually free (1) | - | Free from (3) | Free from | Virtually free (1) |
| Odor (Objectionable) | Virtually free (1) | - | Free from (3) | Free from | Virtually free (1) |
| Oil (Floating) | Virtually free (1) | - | Free from (3) | Free from | Virtually free (1) |
| pH | 6.5-8.3 | No specific recommendation | - | 6.5-8.3 | 6.5-8.3 |
| Settleable solids which form objectionable deposits | Virtually free (1) | - | Free from (3) | Free from | Virtually free (1) |
| Temperature | | | | | |
| Minimum | $15^\circ C$ ($59^\circ F$) | No specific recommendation | - | - | $15^\circ C$ ($59^\circ F$) |
| Maximum | $35^\circ C$ ($94^\circ F$) | No specific recommendation | - | $30^\circ C$ ($85^\circ F$) | $35^\circ C$ ($94^\circ F$) |

(1) Virtually free is used to imply freedom from the undesirable effects of the constituent itself. This recognizes the practical impossibility of complete absence and the inevitability of the presence of potential pollutants to some degree.
(2) Log mean of a minimum of five samples taken over 30 days. Ten percent of the total samples for any 30-day period shall not exceed 400/100ml.
(3) Based on aesthetic quality criteria.

STREAM AND LAKE AESTHETICS
SUMMARY OF WATER QUALITY CRITERIA (all units in mg/l except as noted)

| Parameter | National Academy of Science, 1972 | EPA, Oct. 10, 1975 | National Technical Advisory Committee, April 1, 1968 | Recommended Water Quality Evaluation Criteria |
|---|---|---|---|---|
| Aquatic Growth (substances and conditions which produce undesirable aquatic growth) | Virtually free (1) | Free from | Free from | Virtually free (1) |
| Color | Virtually free (1) | Free from | Free from | Virtually free (1) |
| Floating Debris and Scum | Virtually free (1) | Free from | Free from | Virtually free (1) |
| Odor (Objectionable) | Virtually free (1) | Free from | Free from | Virtually free (1) |
| Oil | Virtually free (1) | Free from | Free from | Virtually free (1) |
| Organics | | | | |
| Chlorophyll a | 0-4 $mg/m^3$ | - | - | 0-4 $mg/m^3$ |
| Phosphate | | | | |
| Total | No specific recommendation | 0.025 (2) 0.05 (3) | No specific recommendation | 0.05 (4) |
| Ortho | No specific recommendation | - | No specific recommendation | - |
| Settleable solids which form objectionable deposits | Virtually free (1) | Free from | Free from | Virtually free (1) |

(1) Virtually free is used to imply freedom from the undesirable effects of the constituent itself. This recognizes the practical impossibility of complete absence and the inevitability of the presence of potential pollutants to some degree.
(2) Suggested standard recommended for lakes.
(3) Suggested standard recommended for streams.
(4) Suggested standard for streams. Suggested standard for lakes is 0.025 mg/l.

INDUSTRIAL WATER SUPPLY

SUMMARY OF WATER QUALITY CRITERIA (all units in mg/l except as noted)

| Parameter | National Academy of Science, 1972 (Petroleum Industry) | National Academy of Science, 1972 (Oil Recovery Injection Water) | National Technical Advisory Committee April 1, 1968 | Recommended Water Quality Evaluation Criteria |
|---|---|---|---|---|
| Alkalinity | 500 | - | - | 500 |
| Bicarbonate | 480 | 280 | 480 | 480 |
| Calcium | 220 | 2,700 | 220 | 220 |
| Chloride | 1,600 | 73,000 | 1,600 | 1,600 |
| Color | 25 units (1) | - | 25 units (1) | 25 units (1) |
| Fluoride | 1.2 | - | 1.2 | 1.2 |
| Hardness | 900 | - | 900 | 900 |
| Iron | 15 | 13 | 15 | 13 |
| Magnesium | 85 | 650 | 86 | 85 |
| Nitrogen | | | | |
| Ammonia ($NH_3$-N) | 33 | - | - | 33 |
| Nitrate ($NO_3$-N) | 2 | - | 2 | 2 |
| pH | 6.0-9.0 | to 6.5 | 6.0-9.0 | 6.0-9.0 |
| Silica | 85 | - | 50 | 50 |
| Solids | | | | |
| Suspended | 5,000 | - | 5,000 | 5,000 |
| Total Dissolved | 3,500 | 119,000 | 3,500 | 3,500 |
| Sulfate | 900 | 42 | 570 | 570 |
| Sulfide | 20 $H_2S$ | - | - | 20 $H_2S$ |

(1) Platinum-cobalt units.

Note: Industrial water supply does not include water quality criteria for coal gasification oil shale recovery and trona processing.

POWER PLANT COOLING

SUMMARY OF WATER QUALITY CRITERIA (all units in mg/l except as noted)

| Parameter | National Academy of Science, 1972 (1) | McKee and Wolf, 1963 (2) | National Technical Advisory Committee April 1, 1968 (1) | Recommended Water Quality Evaluation Criteria (1) |
|---|---|---|---|---|
| Alkalinity | 115 | - | 150 | 150 |
| Aluminum | 0.1 | - | - | 0.1 |
| Bicarbonate | 140 | - | 180 | 140 |
| Calcium | 420 | - | 1,200 | 420 |
| Chloride | 19,000 | - | 22,000 | 20,000 |
| Hardness | 6,250 | 50 | 7,000 | 7,000 |
| Iron | 0.5 | 0.5 | 1.0 | 0.5 |
| Iron + Manganese | - | 0.5 | - | 0.5 |
| Manganese | 0.02 | 0.5 | 0.02 | 0.5 |
| Organics | | | | |
| Meth. Blue Act. | 1 | - | 1.3 | 1.0 |
| pH | - | - | 5.0-8.4 | 5.0-8.4 |
| Phosphate (Total) | - | - | 5 | 5 |
| Silica | 25 | - | 25 | 25 |
| Solids | | | | |
| Suspended | 100 | - | 250 | 250 |
| Total Dissolved | 35,000 | - | 35,000 | 35,000 |
| Sulfate | 2,700 | - | 2,700 | 2,700 |
| Sulfide | - | - | 4 $H_2S$ | 4 $H_2S$ |
| Temperature | $49^{\circ}C$ ($120^{\circ}F$) | - | $49^{\circ}C$ ($120^{\circ}F$) | $49^{\circ}C$ ($120^{\circ}F$) |
| Turbidity | - | 50 | - | 50 |

(1) Based on water quality required for recirculation makeup with brackish water (TDS greater than 1,000mg/l).

(2) No specific recommendation. Values presented are from background information.

# APPENDIX B

## STATE WATER QUALITY STANDARDS

CALIFORNIA
IDAHO
NEVADA
WYOMING
UTAH

Summaries of state water quality standards were taken directly from: Guide to Water Quality Standards of the United States. 1980. American Petroleum Institute, API Pub. No. 4321. Every effort has been made to ensure accuracy. However, users are encouraged to check official state publications before taking any official action regarding suspected violation of water quality standards.

# CALIFORNIA

Standards Adopted: 22 October 1977

Accepted by USEPA

Copies of Current Statewide Standards available from:
Ed Anton
Supervising Water Resource Control Engineer
California Water Resources Board
P.O. Box 100
Sacramento, California 95801
(916) 322-3133

Copies of the 16 basin plans are available for inspection at the Water Resources Board Office.

There is no fee for sending the statewide standards. There may be a fee in the future.

A mailing list for updates is not maintained, but there is a list for receipt of information about hearings, etc.

Responsible Agency: California Water Resources Control Board
P.O. Box 100
Sacramento, California 95801
(916) 322-3133

Contacts: Ed Anton
Supervising Water Resources Control Engineer
(916) 322-3133

Regional Water Quality Control Board Offices, if interested in a certain part of California

Organization: California's water quality regulations are in the California Administrative Code, Title 23, Waters, Chapter 3, State Water Resources Control Board. There are three statewide standards: An oceanwater plan, a policy for bays and estuaries, and a thermal plan. There are 16 basin plans which are not available, except for inspection at the Water Resources Board Office.

Classification: No information is currently available on general use classifications for California waters. However, standards are promulgated by basin, not by use classification.

Mixing Zone Description: For ocean waters, the area of initial dilution is the zone of rapid and irreversible turbulent mixing.

Notable Exceptions: No information is available.

Special Comments: Specific standards vary with receiving water and location in the state. Potential dischargers should contact state or regional officials.

Antidegradation Policy: Contained in a separate document. It is a resolution adopted by the California Water Resources Control Board.

NPDES Permit Authority: California Water Resources Control Board
P.O. Box 100
Sacramento, California 95801
(916) 322-3133

Waste Load Allocation: A program for total daily maximum loading has been initiated, but it is not very far along.

Revisions: Temperature standards may revised soon.

Approved by: Ed Anton
Date: 6 November 1979

## CALIFORNIA

## WATER QUALITY STANDARDS

| Parameter | Six Month Median for Ocean Water[a] |
|---|---|
| **Physical** | |
| Aesthetic conditions (including clarity, floating materials, foam, scum, sediment, garbage, sewage, slicks, and/or sludge) | |
| Color (units) | |
| Conductivity (micromhos/cm) | |
| Gases, dissolved | |
| Odor, threshold (no.) | |
| Oxygen, dissolved (mg/l) | |
| pH | |
| Solids, settleable (ml/l) | |
| Solids, total dissolved (mg/l) | |
| Solids, total suspended (mg/l) | |
| Taste | |
| Temperature (°C) | |
| Temperature (°F) | |
| Temperature, maximum delta T (°C) | |
| Temperature, maximum delta T (°F) | |
| Transparency | |
| Turbidity (FTU) | |
| Turbidity (JTU) | |
| Turbidity (NTU) | |
| Turbidity (Std units) | |
| Turbidity (TU) | |
| **Inorganic** | |
| Acidity (mg/l-$CaCO_3$) | |
| Alkalinity (mg/l-$CaCO_3$) | |
| Ammonia (mg/l-N) | 0.6 |
| Ammonia, undissociated (mg/l-N) | |
| Bicarbonate (mg/l-$CaCO_3$) | |
| Boron (mg/l) | |
| Boron, soluble (mg/l) | |
| Bromates (mg/l) | |
| Bromine (mg/l) | |
| Calcium (mg/l) | |
| Carbonates (mg/l-$CaCO_3$) | |
| Chlorides (mg/l) | |
| Chlorine, total residual (mg/l) | |
| Cyanide (mg/l-CN) | |
| Cyanide, ferro- or ferri- (mg/l-$Fe(CN)^6$) | |
| Fluoride (mg/l) | |
| Fluoride, soluble (mg/l) | |
| Hardness (mg/l-$CaCO_3$) | |
| Hydrogen sulfide (mg/l) | |
| Inorganic substances, dissolved (mg/l) | |
| Magnesium (mg/l) | |
| M.B.A.S. (detergents) (mg/l) | |
| Nitrate (mg/l-N) | |
| Nitrate (mg/l-$NO_3$) | |
| Nitrite (mg/l-N) | |
| Nitrate + Nitrite (mg/l-N) | |
| Nitrogen, total (mg/l-N) | |
| Nitrogen, total inorganic (mg/l-N) | |
| Nitrogen/Phosphorus ratio | |
| Nutrients | |
| Phosphate (mg/l-$PO_4$) | |
| Phosphate (mg/l-P) | |
| Phosphorus (mg/l-P) | |
| Salinity (mg/l) | |

a = No information is available except the six-month median for ocean water.

CALIFORNIA

WATER QUALITY STANDARDS

| Parameter | Six Month Median for Ocean Water[a] |
|---|---|
| **Inorganic (cont.)** | |
| Salts, dissolved (mg/l) | |
| Sodium (mg/l) | |
| Sodium absorption ratio | |
| Sulfate (mg/l) | |
| Sulfide (mg/l) | |
| Uranyl ion (mg/l) | |
| **Toxic Metals (all mg/l)** | |
| Aluminum | |
| Aluminum, soluble | |
| Antimony | |
| Arsenic | 0.008 |
| Arsenic, soluble | |
| Barium | |
| Barium, soluble | |
| Beryllium | |
| Cadmium | 0.003 |
| Chromium | 0.002 |
| Chromium, soluble | |
| Chromium, hexavalent | |
| Chromium, trivalent | |
| Cobalt | |
| Copper | 0.005 |
| Copper, soluble | |
| Iron | |
| Iron, soluble | |
| Lead | 0.008 |
| Lead, soluble | |
| Manganese | |
| Mercury | 0.00014 |
| Molybdenum | |
| Nickel | 0.02 |
| Selenium | |
| Selenium, soluble | |
| Silver | 0.00045 |
| Silver, soluble | |
| Thallium | |
| Uranium | |
| Vanadium | |
| Zinc | 0.02 |
| Zinc, soluble | |
| **Toxic and/or deleterious substances** | |
| **Organics (all mg/l)** | |
| Benzene hexachloride | |
| Benzidine | |
| Biochemical oxygen demand | |
| Biocides | |
| Carbon chloroform extract | |
| Carbon, total organic | |
| Chemical oxygen demand | |
| Chlorinated pesticides | |
| Aldrin | |
| Aldrin plus Dieldrin | |
| Chlordane | |
| Dieldrin | |
| DDT | |
| Endrin | |
| Heptachlor | |
| Heptachlor epoxide | |
| Lindane | |
| Methoxychlor | |

a = No information is available except the six-month median for ocean water.

CALIFORNIA

WATER QUALITY STANDARDS

| Parameter | Six Month Median for Ocean Water[a] |
|---|---|
| **Organics** (all mg/l) (cont.) | |
| Chlorinated pesticides (cont.) | |
| Mirex | |
| Perthane | |
| Toxaphene | |
| Contaminants, trace | |
| Herbicides | |
| 2, 4 D | |
| 2, 4, 5 TP or Silvex | |
| Dalapon | |
| Dicamba | |
| Diquat | |
| Dursban | |
| Simazine | |
| Hydrocarbons | |
| Oil and/or grease | |
| Organic phosphates and carbamates | |
| Orthophosphate pesticides | |
| Ciodrin | |
| Coumaphos | |
| Demeton | |
| Diazinon | |
| Dichlorvos | |
| Endosulfan | |
| Fenthion | |
| Gunthion | |
| Malathion | |
| Naled | |
| Parathion | |
| Phosphaphamidon | |
| TEPP | |
| Pesticides | |
| Petroleum | |
| Phenol | |
| Phenolics/phenolic compounds | |
| Phenols | |
| Phthalate esters | |
| Polychlorinated biphenyls | |
| **Biological** | |
| Actinomycetes colonies, or fungus | |
| Algae | |
| Benthic macroinvertebrates | |
| Chlorophyll a | |
| Coliforms, fecal (#/100 ml) | |
| Coliforms, fecal (geom. mean #/100 ml) | |
| Coliforms, fecal (log mean, #/100 ml) | |
| Coliforms, total (#/100 ml) | |
| Coliforms, total (geom. mean #/100 ml) | |
| Coliforms, total (log mean, #/100 ml) | |
| Coliforms, total (MPN, #/100 ml) | |
| Organisms, pathogenic (#/100 ml) | |
| Plankton count | |
| *Shistosoma mansoni* (#/100 ml) | |
| **Radiological** (pCi/l) | |
| Alpha, dissolved emitters | |
| Alpha, excluding uranium and radon | |

a = No information is available except the six-month median for ocean water.

CALIFORNIA

WATER QUALITY STANDARDS

| Parameter | Six Month Median for Ocean Water[a] |
|---|---|
| Radiological (pCi/l) (cont.) | |
| Alpha, gross | |
| Beta, excluding Potassium 40 | |
| Beta, excluding Strontium 90 | |
| Beta, excluding Strontium 90 and alpha emitters | |
| Beta, gross | |
| Cesium 134 | |
| Plutonium 238, 239, 240 | |
| Radioactive substances | |
| Radionuclides, dissolved | |
| Radionuclides, suspended | |
| Radium 226 | |
| Radium 226 and 228 | |
| Radium 226 and 232 | |
| Radium 228 | |
| Strontium 89 | |
| Strontium 90 | |
| Thorium 230 and 232 | |
| Tritium | |
| Uranium | |

a = No information is available except the six-month median for ocean water.

# IDAHO

Standards Effective: 28 June 1973

Accepted by USEPA

Copies of Current Standards available from:
Custodian of Records
Bureau of Finance
State House
Boise, Idaho 83720

There is a fee for copying the standards
There is a mailing list for updates

Responsible Agency: Department of Health and Welfare
Division of the Environment
Bureau of Water Quality
Boise, Idaho 83720

Contact: Dennis Cray
Sr. Water Resource Analyst
Planning and Standards Section
(208) 384-2215

Organization: The Idaho water quality regulations and standards were adopted by the Idaho State Board of Environmental and Community Service pursuant to the Idaho Code and Idaho Session Laws 1973. The Idaho water quality standards and waste water treatment requirements are divided into 12 parts plus an appendix: I. introduction - legal authority; II. definitions; III. general requirements - statements regarding policy towards water rights, protected waters, water treatment, and antidegradation; IV. restrictions on the discharge of sewage and industrial wastewaters and human activities which affect water quality in the waters of the state - statements of policy toward wastewater discharges and department exceptions to short-term activities which may lower water quality; V. maintenance of standards of quality - required degree of wastewater treatment, mixing zones, revisions and sampling; VI. water use classification; VII. general water quality standards for waters of the state; VIII. specific water quality standards; IV. specific water quality standards for Class E waters; X. regulations governing waste water discharges; XI. regulations governing specific activities - disinfection and treatment and/or disposal of wastewaters; XII. implementation; and appendix - contains a listing of state waters according to basin, and the uses to be protected.

Classification: Waters are classified according to use as follows. Class A1, primary contact, is restricted to lakes and impoundments in which exceptionally high water quality exists. Class A2, primary contact, involves the remainder of the primary contact recreational waters. Class B, secondary contact - recreational waters, are suitable for aquatic life, propagation of fisheries, boating and wading. Class E, excepted waters, are those waters not compatible with recreational uses.

Mixing Zone Description: Little information is contained within the standards regarding size and designation of mixing zones. Water quality outside of the mixing zones shall be maintained.

Notable Exceptions: Activities that violate the standards may be approved by the Department on a case-by-case basis.

Special Comments: Numerical values are standards.

Antidegradation Policy: The policy is contained in Part III.D.

NPDES Permit Authority: The USEPA has permitting authority.

Waste Load Allocation: Total daily maximum loading criteria are not included.

Revisions: Anticipated revisions are set for November 1979 or April 1980. The revisions contain a more realistic antidegradation policy.

**********************************************************************

PLEASE NOTE: Idaho water quality standards have been revised recently. See the following page concerning significant revisions. The information contained herein, except for the following page, is a summary of the old standards.

**********************************************************************

No comments were received from the State of Idaho.

The following information is supplied by the preparer of this technical guide:

Idaho Water Quality Standards have been revised. Significant changes have occurred in the standards. Of special interest is the following change concerning nonpoint sources and Best Management Practices from page 42 of the standards.

1-2300 RESTRICTIONS ON DISCHARGES AND ON ACTIVITIES WHICH AFFECT WATER QUALITY

---

.04 Limitations to Nonpoint Source Restrictions. So long as a nonpoint source activity is being conducted in accordance with applicable rules, regulations and best management practices as referenced in Manual Section 1-2300.05, or in the absence of referenced applicable best management practices, conducted in a manner that demonstrates a knowledgeable and reasonable effort to minimize resulting adverse water quality impacts, the activity will not be subject to conditions or legal actions based on Manual Sections 1-2300.01 or 1-2300.02(a). (1-30-80)

.05 Approved Best Management Practices. The following are approved best management practices for the purpose of Manual Section 1-2300.04: (1-30-80)

(a) "Idaho Forest Practices Rules," as adopted by the Board of Land Commissioners; and (1-30-80)

(b) "Rules Governing Solid Waste Management," Title 1, Chapter 6, Rules and Regulations of the Department of Health and Welfare; and (1-30-80)

(c) "Rules Governing Subsurface and Individual Sewage Disposal Systems," Title 1, Chapter 3, Rules and Regulations of the Department of Health and Welfare; and (1-30-80)

(d) "Rules and Regulations and Minimum Standards for Stream-channel Alterations," as adopted by the Board of Water Resources; and (1-30-80)

(e) For the Spokane Valley Rathdrum Prairie Aquifer, "Rathdrum Prairie Sewage Disposal Regulations," as adopted by the Panhandle District Health Department Board of Health and approved by the Idaho Board of Health and Welfare. (1-30-80)

IDAHO

WATER QUALITY STANDARDS

| Parameter | Class $A_1$ Primary Contact | Class $A_2$ Primary Contact | Class B Secondary Contact | Class E Excepted Waters |
|---|---|---|---|---|
| **Physical** | | | | |
| Aesthetic conditions (including clarity, floating materials, foam, scum, sediment, garbage, sewage, slicks, and/or sludge) | narrative | narrative | narrative | narrative |
| Color (units) | | | | |
| Conductivity (micromhos/cm) | | | | |
| Gases, dissolved | narrative | narrative | narrative | narrative |
| Odor, threshold (no.) | | | | |
| Oxygen, dissolved (mg/l) | 6.0,narrative | 6.0,narrative | 6.0,narrative | 6.0,narrative |
| pH | 6.5-9.0,narrative | 6.5-9.0,narrative | 6.5-9.0,narrative | 6.5-9.0,narrative |
| Solids, settleable (ml/l) | | | | |
| Solids, total dissolved (mg/l) | | | | |
| Solids, total suspended (mg/l) | | | | |
| Taste | | | | |
| Temperature (°C) | | | | |
| Temperature (°F) | narrative | narrative | narrative | narrative |
| Temperature, maximum delta T (°C) | | | | |
| Temperature, maximum delta T (°F) | | | | |
| Transparency | | | | |
| Turbidity (FTU) | | | | |
| Turbidity (JTU) | 5,narrative | 5,narrative | 5,narrative | 5,narrative |
| Turbidity (NTU) | | | | |
| Turbidity (Std units) | | | | |
| Turbidity (TU) | | | | |
| **Inorganic** | | | | |
| Acidity (mg/l-$CaCO_3$) | | | | |
| Alkalinity (mg/l-$CaCO_3$) | | | | |
| Ammonia (mg/l-N) | | | | |
| Ammonia, undissociated (mg/l-N) | | | | |
| Bicarbonate (mg/l-$CaCO_3$) | | | | |
| Boron (mg/l) | | | | |
| Boron, soluble (mg/l) | | | | |
| Bromates (mg/l) | | | | |
| Bromine (mg/l) | | | | |
| Calcium (mg/l) | | | | |
| Carbonates (mg/l-$CaCO_3$) | | | | |
| Chlorides (mg/l) | | | | |
| Chlorine, total residual (mg/l) | | | | |
| Cyanide (mg/l-CN) | | | | |
| Cyanide, ferro- or ferri- (mg/l-$Fe(CN)^6$) | | | | |
| Fluoride (mg/l) | | | | |
| Fluoride, soluble (mg/l) | | | | |
| Hardness (mg/l-$CaCO_3$) | | | | |
| Hydrogen sulfide (mg/l) | | | | |
| Inorganic substances, dissolved (mg/l) | | | | |
| Magnesium (mg/l) | | | | |
| M.B.A.S. (detergents) (mg/l) | | | | |
| Nitrate (mg/l-N) | | | | |
| Nitrate (mg/l-$NO_3$) | | | | |
| Nitrite (mg/l-N) | | | | |
| Nitrate + Nitrite (mg/l-N) | | | | |
| Nitrogen, total (mg/l-N) | | | | |
| Nitrogen, total inorganic (mg/l-N) | | | | |
| Nitrogen/Phosphorus ratio | | | | |
| Nutrients | narrative | narrative | narrative | narrative |
| Phosphate (mg/l-$PO_4$) | | | | |
| Phosphate (mg/l-P) | | | | |
| Phosphorus (mg/l-P) | | | | |
| Salinity (mg/l) | | | | |

IDAHO

WATER QUALITY STANDARDS

| Parameter | Class $A_1$ Primary Contact | Class $A_2$ Primary Contact | Class B Secondary Contact | Class E Excepted Waters |
|---|---|---|---|---|
| Inorganic (cont.) | | | | |
| Salts, dissolved (mg/l) | | | | |
| Sodium (mg/l) | | | | |
| Sodium absorption ratio | | | | |
| Sulfate (mg/l) | | | | |
| Sulfide (mg/l) | | | | |
| Uranyl ion (mg/l) | | | | |
| Toxic Metals (all mg/l) | | | | |
| Aluminum | | | | |
| Aluminum, soluble | | | | |
| Antimony | | | | |
| Arsenic | | | | |
| Arsenic, soluble | | | | |
| Barium | | | | |
| Barium, soluble | | | | |
| Beryllium | | | | |
| Cadmium | | | | |
| Chromium | | | | |
| Chromium, soluble | | | | |
| Chromium, hexavalent | | | | |
| Chromium, trivalent | | | | |
| Cobalt | | | | |
| Copper | | | | |
| Copper, soluble | | | | |
| Iron | | | | |
| Iron, soluble | | | | |
| Lead | | | | |
| Lead, soluble | | | | |
| Manganese | | | | |
| Mercury | | | | |
| Molybdenum | | | | |
| Nickel | | | | |
| Selenium | | | | |
| Selenium, soluble | | | | |
| Silver | | | | |
| Silver, soluble | | | | |
| Thallium | | | | |
| Uranium | | | | |
| Vanadium | | | | |
| Zinc | | | | |
| Zinc, soluble | | | | |
| Toxic and/or deleterious substances | narrative | narrative | narrative | narrative |
| Organics (all mg/l) | | | | |
| Benzene hexachloride | | | | |
| Benzidine | | | | |
| Biochemical oxygen demand | | | | |
| Biocides | | | | |
| Carbon chloroform extract | | | | |
| Carbon, total organic | | | | |
| Chemical oxygen demand | | | | |
| Chlorinated pesticides | | | | |
| Aldrin | | | | |
| Aldrin plus Dieldrin | | | | |
| Chlordane | | | | |
| Dieldrin | | | | |
| DDT | | | | |
| Endrin | | | | |
| Heptachlor | | | | |
| Heptachlor epoxide | | | | |
| Lindane | | | | |
| Methoxychlor | | | | |

IDAHO

WATER QUALITY STANDARDS

| Parameter | Class $A_1$ Primary Contact | Class $A_2$ Primary Contact | Class B Secondary Contact | Class E Excepted Waters |
|---|---|---|---|---|
| **Organics** (all mg/l) (cont.) | | | | |
| Chlorinated pesticides (cont.) | | | | |
| Mirex | | | | |
| Perthane | | | | |
| Toxaphene | | | | |
| Contaminants, trace | | | | |
| Herbicides | | | | |
| 2, 4 D | | | | |
| 2, 4, 5 TP or Silvex | | | | |
| Dalapon | | | | |
| Dicamba | | | | |
| Diquat | | | | |
| Dursban | | | | |
| Simazine | | | | |
| Hydrocarbons | | | | |
| Oil and/or grease | | | | |
| Organic phosphates and carbamates | | | | |
| Orthophosphate pesticides | | | | |
| Ciodrin | | | | |
| Coumaphos | | | | |
| Demeton | | | | |
| Diazinon | | | | |
| Dichlorvos | | | | |
| Endosulfan | | | | |
| Fenthion | | | | |
| Gunthion | | | | |
| Malathion | | | | |
| Naled | | | | |
| Parathion | | | | |
| Phosphaphamidon | | | | |
| TEPP | | | | |
| Pesticides | | | | |
| Petroleum | | | | |
| Phenol | | | | |
| Phenolics/phenolic compounds | | | | |
| Phenols | | | | |
| Phthalate esters | | | | |
| Polychlorinated biphenyls | | | | |
| **Biological** | | | | |
| Actinomycetes colonies, or fungus | | | | |
| Algae | | | | |
| Benthic macroinvertebrates | | | | |
| Chlorophyll a | | | | |
| Coliforms, fecal (#/100 ml) | | | | |
| Coliforms, fecal (geom. mean #/100 ml) | 10,narrative | 50,narrative | 200,narrative | 50,narrative |
| Coliforms, fecal (log mean, #/100 ml) | | | | |
| Coliforms, total (#/100 ml) | | | | |
| Coliforms, total (geom. mean #/100 ml) | 50,narrative | 240,narrative | 1000,narrative | 240,narrative |
| Coliforms, total (log mean, #/100 ml) | | | | |
| Coliforms, total (MPN, #/100 ml) | | | | |
| Organisms, pathogenic (#/100 ml) | | | | |
| Plankton count | | | | |
| *Shistosoma mansoni* (#/100 ml) | | | | |
| **Radiological** (pCi/l) | | | | |
| Alpha, dissolved emitters | | | | |
| Alpha, excluding uranium and radon | | | | |

IDAHO

WATER QUALITY STANDARDS

| Parameter | Class $A_1$ Primary Contact | Class $A_2$ Primary Contact | Class B Secondary Contact | Class E Excepted Waters |
|---|---|---|---|---|
| Radiological (pCi/l) (cont.) | | | | |
| Alpha, gross | | | | |
| Beta, excluding Potassium 40 | | | | |
| Beta, excluding Strontium 90 | | | | |
| Beta, excluding Strontium 90 and alpha emitters | | | | |
| Beta, gross | | | | |
| Cesium 134 | | | | |
| Plutonium 238, 239, 240 | | | | |
| Radioactive substances | narrative | narrative | narrative | narrative |
| Radionuclides, dissolved | | | | |
| Radionuclides, suspended | | | | |
| Radium 226 | | | | |
| Radium 226 and 228 | | | | |
| Radium 226 and 232 | | | | |
| Radium 228 | | | | |
| Strontium 89 | | | | |
| Strontium 90 | | | | |
| Thorium 230 and 232 | | | | |
| Tritium | | | | |
| Uranium | | | | |

# NEVADA

Standards Adopted: January 1979

Accepted by USEPA

Copies of Current Standards available from:
Ernest G. Gregory
Administrator
Division of Environmental Protection
201 South Fall Street
Carson City, Nevada 89710
(702) 885-4670

There is no fee for sending the standards
It is not known whether or not a mailing list for updates is maintained

Responsible Agency: Division of Environmental Protection
201 South Fall Street
Carson City, Nevada 89710
(702) 885-4670

Contact: Ernest G. Gregory
Administrator
(702) 885-4670

Organization: Nevada water quality standards are composed of four sections (articles) and two appendices. Article 1 contains definitions. Article 2 titled "Administration of Discharge Permits," contains scope and purposes; permits and application; notice and public participation; terms and conditions of permits; duration and reissuance of permits; monitoring, recording and reporting of discharges; modification, suspension and revocation of permits; disposal of pollutants into wells; emergency powers; and violations: remedies. Article 3 titled "Administration of Treatment Works," contains design, construction and location. Article 4, titled "Water Quality Standards contains water quality criteria related to beneficial uses (general definitions of required quality for each water use), narrative standards applicable to all waters of the state (includes exceptions and mixing zone standards), and classification of waters (defines and provides specifications for each of four classes of waters and gives numerical standards for selected waters). There are two appendices: Appendix A - guide for formulating water quality standards for the interstate waters of the Colorado River system, and Appendix B - Colorado River basin states - cooperation.

Classification: Nevada waters are composed of four classes: Class A waters - drinking water supply with treatment by disinfection only, suitable for aquatic life habitat, agriculture and recreation (no industrial development or intensive agriculture is allowed); Class B waters - drinking water supply with treatment by disinfection and filtration only, agriculture, wildlife propagation, industrial supply and recreation; Class C waters - domestic water supply following complete treatment, agriculture, wildlife propagation, industrial supply and recreation; Class D waters - boating, aquatic life, agriculture and industrial supply, except for food processing.

Mixing Zone Description: Mixing zones are recognized as necessary by the Director. Mixing zone water must not exceed acute toxicity values nor endanger human health or indigenous aquatic life. Mixing zones are limited to 1/3 of the cross-sectional area of the receiving water.

Notable Exceptions: Exceptions are provided for natural conditions that are outside established limits, and for periods of extremely high or low flow.

Special Comments: Numerical values are standards.

Antidegradation Policy: Contained in the Preamble, Page 1.

NPDES Permit Authority: Division of Environmental Protection
201 South Fall Street
Carson City, Nevada 89710

Waste Load Allocation: Total daily maximum loadings have been implemented, but pollutants and water bodies involved were not specified.

Revisions: Revisions were adopted and approved in January 1979.

Approved by: Dr. Geoffrey A. Ekechakam
Date: 8 November 1979

# NEVADA

## WATER QUALITY STANDARDS

| Parameter | Class A Waters | Class B Waters | Class C Waters | Class D Waters |
|---|---|---|---|---|
| **Physical** | | | | |
| Aesthetic conditions (including clarity, floating materials, foam, scum, sediment, garbage, sewage, slicks, and/or sludge) | narrative | narrative | narrative | narrative |
| Color (units) | narrative | narrative | narrative | narrative |
| Conductivity (micromhos/cm) | | | | |
| Gases, dissolved | | | | |
| Odor, threshold (no.) | | | | |
| Oxygen, dissolved (mg/l) | 6.0 | 5.0-6.0, narrative | 5.0-6.0, narrative | 3.0 |
| pH | 6.5-8.5 | 6.5-8.5 | 6.5-8.5 | 6.0-9.0 |
| Solids, settleable (ml/l) | narrative | narrative | narrative | narrative |
| Solids, total dissolved (mg/l) | 500, narrative | 500, narrative | 500, narrative | |
| Solids, total suspended (mg/l) | | | | |
| Taste | | | | |
| Temperature (°C) | 20, narrative | 20-24, narrative | 20-34, narrative | |
| Temperature (°F) | | | | |
| Temperature, maximum delta T (°C) | | | | |
| Temperature, maximum delta T (°F) | | | | |
| Transparency | | | | |
| Turbidity (FTU) | | | | |
| Turbidity (JTU) | | | | |
| Turbidity (NTU) | | | | |
| Turbidity (Std units) | | | | |
| Turbidity (TU) | narrative | narrative | narrative | narrative |
| **Inorganic** | | | | |
| Acidity (mg/l-$CaCO_3$) | | | | |
| Alkalinity (mg/l-$CaCO_3$) | | | | |
| Ammonia (mg/l-N) | | | | |
| Ammonia, undissociated (mg/l-N) | | | | |
| Bicarbonate (mg/l-$CaCO_3$) | | | | |
| Boron (mg/l) | | | | |
| Boron, soluble (mg/l) | | | | |
| Bromates (mg/l) | | | | |
| Bromine (mg/l) | | | | |
| Calcium (mg/l) | | | | |
| Carbonates (mg/l-$CaCO_3$) | | | | |
| Chlorides (mg/l) | | | | |
| Chlorine, total residual (mg/l) | | | | |
| Cyanide (mg/l-CN) | | | | |
| Cyanide, ferro- or ferri- (mg/l-$Fe(CN)^6$) | | | | |
| Fluoride (mg/l) | | | | |
| Fluoride, soluble (mg/l) | | | | |
| Hardness (mg/l-$CaCO_3$) | | | | |
| Hydrogen sulfide (mg/l) | | | | |
| Inorganic substances, dissolved (mg/l) | | | | |
| Magnesium (mg/l) | | | | |
| M.B.A.S. (detergents) (mg/l) | | | | |
| Nitrate (mg/l-N) | | | | |
| Nitrate (mg/l-$NO_3$) | | | | |
| Nitrite (mg/l-N) | | | | |
| Nitrate + Nitrite (mg/l-N) | | | | |
| Nitrogen, total (mg/l-N) | | | | |
| Nitrogen, total inorganic (mg/l-N) | | | | |
| Nitrogen/Phosphorus ratio | | | | |
| Nutrients | | | | |
| Phosphate (mg/l-$PO_4$) | narrative | 0.3(mg/l) | 1.0(mg/l) | |
| Phosphate (mg/l-P) | | | | |
| Phosphorus (mg/l-P) | | | | |
| Salinity (mg/l) | | | | |

## NEVADA

## WATER QUALITY STANDARDS

| Parameter | Class A Waters | Class B Waters | Class C Waters | Class D Waters |
|---|---|---|---|---|
| Inorganic (cont.) | | | | |
| Salts, dissolved (mg/l) | | | | |
| Sodium (mg/l) | | | | |
| Sodium absorption ratio | | | | |
| Sulfate (mg/l) | | | | |
| Sulfide (mg/l) | | | | |
| Uranyl ion (mg/l) | | | | |
| Toxic Metals (all mg/l) | narrative[a] | narrative[a] | narrative[a] | narrative[a] |
| Aluminum | | | | |
| Aluminum, soluble | | | | |
| Antimony | | | | |
| Arsenic | | | | |
| Arsenic, soluble | | | | |
| Barium | | | | |
| Barium, soluble | | | | |
| Beryllium | | | | |
| Cadmium | | | | |
| Chromium | | | | |
| Chromium, soluble | | | | |
| Chromium, hexavalent | | | | |
| Chromium, trivalent | | | | |
| Cobalt | | | | |
| Copper | | | | |
| Copper, soluble | | | | |
| Iron | | | | |
| Iron, soluble | | | | |
| Lead | | | | |
| Lead, soluble | | | | |
| Manganese | | | | |
| Mercury | | | | |
| Molybdenum | | | | |
| Nickel | | | | |
| Selenium | | | | |
| Selenium, soluble | | | | |
| Silver | | | | |
| Silver, soluble | | | | |
| Thallium | | | | |
| Uranium | | | | |
| Vanadium | | | | |
| Zinc | | | | |
| Zinc, soluble | | | | |
| Toxic and/or deleterious substances | narrative | narrative | narrative | narrative |
| Organics (all mg/l) | | | | |
| Benzene hexachloride | | | | |
| Benzidine | | | | |
| Biochemical oxygen demand | | | | |
| Biocides | | | | |
| Carbon chloroform extract | | | | |
| Carbon, total organic | | | | |
| Chemical oxygen demand | | | | |
| Chlorinated pesticides | b | b | b | b |
| Aldrin | | | | |
| Aldrin plus Dieldrin | | | | |
| Chlordane | | | | |
| Dieldrin | | | | |
| DDT | | | | |
| Endrin | | | | |
| Heptachlor | | | | |
| Heptachlor epoxide | | | | |
| Lindane | | | | |
| Methoxychlor | | | | |

a = Toxic levels have been established for chromium, iron, mercury, lead, selenium, and several other metals. Allowable concentrations of these toxicants are applicable to selected water segments noted in the standards.

b = Toxicity levels have been established for several chlorinated and orthophosphate pesticides. Allowable concentrations depend on stream segment and particular water use within each classification.

NEVADA

WATER QUALITY STANDARDS

| Parameter | Class A Waters | Class B Waters | Class C Waters | Class D Waters |
|---|---|---|---|---|
| Organics (all mg/l) (cont.) | | | | |
| Chlorinated pesticides (cont.) | | | | |
| Mirex | | | | |
| Perthane | | | | |
| Toxaphene | | | | |
| Contaminants, trace | | | | |
| Herbicides | | | | |
| 2, 4 D | | | | |
| 2, 4, 5 TP or Silvex | | | | |
| Dalapon | | | | |
| Dicamba | | | | |
| Diquat | | | | |
| Dursban | | | | |
| Simazine | | | | |
| Hydrocarbons | | | | |
| Oil and/or grease | narrative | narrative | narrative | narrative |
| Organic phosphates and carbamates | | | | |
| Orthophosphate pesticides | b | b | b | b |
| Ciodrin | | | | |
| Coumaphos | | | | |
| Demeton | | | | |
| Diazinon | | | | |
| Dichlorvos | | | | |
| Endosulfan | | | | |
| Fenthion | | | | |
| Gunthion | | | | |
| Malathion | | | | |
| Naled | | | | |
| Parathion | | | | |
| Phosphaphamidon | | | | |
| TEPP | | | | |
| Pesticides | | | | |
| Petroleum | | | | |
| Phenol | | | | |
| Phenolics/phenolic compounds | | | | |
| Phenols | | | | |
| Phthalate esters | | | | |
| Polychlorinated biphenyls | | | | |
| Biological | | | | |
| Actinomycetes colonies, or fungus | | | | |
| Algae | | | | |
| Benthic macroinvertebrates | | | | |
| Chlorophyll a | | | | |
| Coliforms, fecal (#/100 ml) | | | | |
| Coliforms, fecal (geom. mean #/100 ml) | 200 | 200 | 1000 | |
| Coliforms, fecal (log mean, #/100 ml) | | | | |
| Coliforms, total (#/100 ml) | | | | |
| Coliforms, total (geom. mean #/100 ml) | | | | |
| Coliforms, total (log mean, #/100 ml) | | | | |
| Coliforms, total (MPN, #/100 ml) | | | | |
| Organisms, pathogenic (#/100 ml) | | | | |
| Plankton count | | | | |
| Shistosoma mansoni (#/100 ml) | | | | |
| Radiological (pCi/l) | | | | |
| Alpha, dissolved emitters | | | | |
| Alpha, excluding uranium and radon | | | | |

b = Toxicity levels have been established for several chlorinated and orthophosphate pesticides. Allowable concentrations depend on stream segment and particular water use within each classification.

NEVADA

WATER QUALITY STANDARDS

| Parameter | Class A Waters | Class B Waters | Class C Waters | Class D Waters |
|---|---|---|---|---|
| Radiological (pCi/l) (cont.) | | | | |
| Alpha, gross | | | | |
| Beta, excluding Potassium 40 | | | | |
| Beta, excluding Strontium 90 | | | | |
| Beta, excluding Strontium 90 and alpha emitters | | | | |
| Beta, gross | | | | |
| Cesium 134 | | | | |
| Plutonium 238, 239, 240 | | | | |
| Radioactive substances | narrative | narrative | narrative | narrative |
| Radionuclides, dissolved | | | | |
| Radionuclides, suspended | | | | |
| Radium 226 | | | | |
| Radium 226 and 228 | | | | |
| Radium 226 and 232 | | | | |
| Radium 228 | | | | |
| Strontium 89 | | | | |
| Strontium 90 | | | | |
| Thorium 230 and 232 | | | | |
| Tritium | | | | |
| Uranium | | | | |

# UTAH

Standards Adopted: 18 May 1965

Standard Effective: 23 October 1978

Not accepted by USEPA (still negotiating some areas)

Copies of Current Standards available from:
Marv Maxell
Section Chief, Monitoring
Utah Health Department
Bureau Water Pollution Control
150 W. N. Temple Room 410
Salt Lake City, Utah 84110
(801) 533-6146

There is no fee for sending the standards
There is no mailing list for updates

Responsible Agency: Utah Bureau of Water Pollution Control
P.O. Box 2500
Salt Lake City, Utah 84110

Contacts: Marv Maxell
Section Chief, Monitoring
(801) 533-6146

Calvin Sudweeks
Executive Secretary Water Pollution Committee
(801) 533-6146

Organization: Utah's standards of quality for waters of the state are contained in Part II of five parts comprising wastewater disposal regulations. Contents include: public policy, authority, scope, antidegradation policy; Colorado River salinity standards; mixing zones; use designations, Classes 1-6; water quality standards; protection of downstream uses; intermittent waters; laboratory and field analyses; public participation; and appendices A-D.

Classification: There are six classes of waters designated. Class 1 is for domestic water supply. Class 1A is protected for domestic purposes without treatment. Class 1B is protected for domestic purposes with prior disinfection. Class 1C is protected for domestic purposes with prior treatment by standard complete treatment processes as required by the Utah State Department of Health. Class 2 is protected for in-stream recreational use and aesthetics. Class 2A is protected for swimming. Class 2B is protected for secondary contact. Class 3 is protected for in-stream use by beneficial aquatic wildlife. Class 3A is protected for cold water species. Class 3B is protected for warm water species. Class 3C is protected for non-game fish and other aquatic life. Class 3D is protected for waterfowl. Class 4 is protected for agricultural uses. Class 5 is protected for industrial uses. Class 6 is protected for other uses not previously described.

Mixing Zone Description: The zone shall be small in extent and must not form a barrier to migrating aquatic life.

Notable Exceptions: Exceptions are in Section 2.9 for both high and low (7 day, 10 year) flows.

Special Comments: Numerical values are standards.

Antidegradation Policy: Contained in Part II, 2.3.1,2 (Pages 3 & 4), anti-degradation policy.

NPDES Permit Authority: The USEPA has permitting authority in Utah.

Waste Load Allocation: Utah will initiate a total daily maximum loading program when required to do so by the USEPA.

Revisions: Revisions will be made in 1981 according to the schedule required by the USEPA.

Approved by: Marv Maxwell
Date: 9 November 1979

## UTAH

## WATER QUALITY STANDARDS

| Parameter | Domestic Source | | | Recreational & Aesthetics | | Aquatic & Wildlife[a] | | | General Standards |
|---|---|---|---|---|---|---|---|---|---|
| | 1A | 1B | 1C | 2A | 2B | 3A | 3B | 3D | |
| **Physical** | | | | | | | | | |
| Aesthetic conditions (including clarity, floating materials, foam, scum, sediment, garbage, sewage, slicks, and/or sludge) | | | | | | | | | narrative |
| Color (units) | | | | | | | | | narrative |
| Conductivity (micromhos/cm) | | | | | | | | | |
| Gases, dissolved | CBC | CBC | CBC | CBC | CBC | nar | nar | CBC | CBC |
| Odor, threshold (no.) | | | | | | | | | narrative |
| Oxygen, dissolved (mg/l) | CBC | CBC | 5.5,nar | 5.5,nar | 5.5,nar | 6.0,nar | 5.5,nar | 5.5,nar | CBC |
| pH | 6.5-9.0 | 6.5-9.0 | 6.5-9.0 | 6.5-9.0 | 6.5-9.0 | 6.5-9.0 | 6.5-9.0 | 6.5-9.0 | 6.5-9.0 |
| Solids, settleable (ml/l) | | | | | | | | | |
| Solids, total dissolved (mg/l) | CBC | CBC | CBC | CBC | CBC | CBC | CBC | CBC | 1200,nar |
| Solids, total suspended (mg/l) | | | | | | | | | |
| Taste | | | | | | | | | narrative |
| Temperature (°C) | CBC | CBC | CBC | CBC | CBC | 20 | 27 | CBC | CBC |
| Temperature (°F) | | | | | | | | | |
| Temperature, maximum delta T (°C) | CBC | CBC | CBC | CBC | CBC | 2 | 4 | CBC | CBC |
| Temperature, maximum delta T (°F) | | | | | | | | | |
| Transparency | | | | | | | | | |
| Turbidity (FTU) | | | | | | | | | |
| Turbidity (JTU) | | | | | | | | | |
| Turbidity (NTU) | | | | | | | | | |
| Turbidity (Std units) | | | | | | | | | |
| Turbidity (TU) | CBC | CBC | CBC | nar | nar | nar | nar | nar | CBC |
| **Inorganic** | | | | | | | | | |
| Acidity (mg/l-$CaCO_3$) | | | | | | | | | |
| Alkalinity (mg/l-$CaCO_3$) | | | | | | | | | |
| Ammonia (mg/l-N) | CBC | CBC | CBC | CBC | CBC | | | CBC | CBC |
| Ammonia, undissociated (mg/l-N) | | | | | | 0.02 | 0.02 | | |
| Bicarbonate (mg/l-$CaCO_3$) | | | | | | | | | |
| Boron (mg/l) | CBC | CBC | CBC | CBC | CBC | CBC | CBC | CBC | 0.75 |
| Boron, soluble (mg/l) | | | | | | | | | |
| Bromates (mg/l) | | | | | | | | | |
| Bromine (mg/l) | | | | | | | | | |
| Calcium (mg/l) | | | | | | | | | |
| Carbonates (mg/l-$CaCO_3$) | | | | | | | | | |
| Chlorides (mg/l) | | | | | | | | | |
| Chlorine, total residual (mg/l) | CBC | CBC | CBC | CBC | CBC | 0.002 | 0.01 | CBC | CBC |
| Cyanide (mg/l-CN) | CBC | CBC | CBC | CBC | CBC | 0.005 | 0.005 | CBC | CBC |
| Cyanide, ferro- or ferri- (mg/l-$Fe(CN)_6$) | | | | | | | | | |
| Fluoride (mg/l) | | | | | | | | | |
| Fluoride, soluble (mg/l) | 1.4-2.4, nar | 1.4-2.4, nar | 1.4-2.4, nar | CBC | CBC | CBC | CBC | CBC | CBC |
| Hardness (mg/l-$CaCO_3$) | | | | | | | | | |
| Hydrogen sulfide (mg/l) | CBC | CBC | CBC | CBC | CBC | 0.002 | 0.002 | CBC | CBC |
| Inorganic substances, dissolved (mg/l) | | | | | | | | | |
| Magnesium (mg/l) | | | | | | | | | |
| M.B.A.S. (detergents) (mg/l) | | | | | | | | | |
| Nitrate (mg/l-N) | | | | | | | | | |
| Nitrate (mg/l-$NO_3$) | | | | | | | | | |
| Nitrite (mg/l-N) | | | | | | | | | |
| Nitrate + Nitrite (mg/l-N) | | | | | | | | | |
| Nitrogen, total (mg/l-N) | | | | | | | | | |
| Nitrogen, total inorganic (mg/l-N) | | | | | | | | | |
| Nitrogen/Phosphorus ratio | | | | | | | | | |
| Nutrients | | | | | | | | | |
| Phosphate (mg/l-$PO_4$) | | | | | | | | | |
| Phosphate (mg/l-P) | | | | | | | | | |
| Phosphorus (mg/l-P) | CBC | CBC | CBC | 0.05 | 0.05 | 0.05 | 0.05 | CBC | CBC |
| Salinity (mg/l) | | | | | | | | | |

KEY: nar = narrative
CBC = case-by-case
a = Class 3C is a case-by-case consideration, except for 13 segments designated in Appendix C where numeric criteria are listed.

UTAH

WATER QUALITY STANDARDS

| Parameter | Domestic Source 1A | 1B | 1C | Recreational & Aesthetics 2A | 2B | Aquatic & Wildlife[a] 3A | 3B | 3D | General Standards |
|---|---|---|---|---|---|---|---|---|---|
| **Inorganic** (cont.) | | | | | | | | | |
| Salts, dissolved (mg/l) | | | | | | | | | |
| Sodium (mg/l) | | | | | | | | | |
| Sodium absorption ratio | | | | | | | | | |
| Sulfate (mg/l) | | | | | | | | | |
| Sulfide (mg/l) | | | | | | | | | |
| Uranyl ion (mg/l) | | | | | | | | | |
| **Toxic Metals** (all mg/l) | | | | | | | | | |
| Aluminum | | | | | | | | | |
| Aluminum, soluble | | | | | | | | | |
| Antimony | | | | | | | | | |
| Arsenic | | | | | | | | | |
| Arsenic, soluble | 0.05 | 0.05 | 0.05 | CBC | CBC | CBC | CBC | CBC | 0.1 |
| Barium | | | | | | | | | |
| Barium, soluble | 1 | 1 | 1 | CBC | CBC | | | | |
| Beryllium | | | | | | | | | |
| Cadmium | 0.010[b] | 0.010[b] | 0.010[b] | CBC | CBC | 0.004,[b] nar | 0.004,[b] nar | CBC | |
| Chromium | | | | | | | | | |
| Chromium, soluble | 0.05 | 0.05 | 0.05 | CBC | CBC | 0.10 | 0.10 | 0.10 | 0.10 |
| Chromium, hexavalent | | | | | | | | | |
| Chromium, trivalent | | | | | | | | | |
| Cobalt | | | | | | | | | |
| Copper | | | | | | | | | |
| Copper, soluble | CBC | CBC | CBC | CBC | CBC | 0.01 | 0.01 | CBC | 0.2 |
| Iron | CBC | CBC | CBC | CBC | CBC | 1.0 | 1.0 | 1.0 | CBC |
| Iron, soluble | | | | | | | | | |
| Lead | | | | | | | | | |
| Lead, soluble | 0.05 | 0.05 | 0.05 | CBC | CBC | 0.05 | 0.05 | CBC | 0.1 |
| Manganese | | | | | | | | | |
| Mercury | 0.002 | 0.002 | 0.002 | CBC | CBC | 0.00005 | 0.00005 | 0.00005 | CBC |
| Molyboenum | | | | | | | | | |
| Nickel | | | | | | | | | |
| Selenium | | | | | | | | | |
| Selenium, soluble | 0.01 | 0.01 | 0.01 | CBC | CBC | 0.05 | 0.05 | CBC | 0.05 |
| Silver | | | | | | | | | |
| Silver, soluble | 0.05 | 0.05 | 0.05 | CBC | CBC | 0.01 | 0.01 | CBC | CBC |
| Thallium | | | | | | | | | |
| Uranium | | | | | | | | | |
| Vanadium | | | | | | | | | |
| Zinc | | | | | | | | | |
| Zinc, soluble | CBC | CBC | CBC | CBC | CBC | 0.05 | 0.05 | CBC | CBC |
| **Toxic and/or deleterious substances** | | | | | | | | | |
| **Organics** (all mg/l) | | | | | | | | | |
| Benzene hexachloride | | | | | | | | | |
| Benzidine | | | | | | | | | |
| Biochemical oxygen demand | CBC | CBC | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Biocides | | | | | | | | | |
| Carbon chloroform extract | | | | | | | | | |
| Carbon, total organic | | | | | | | | | |
| Chemical oxygen demand | | | | | | | | | |
| Chlorinated pesticides | | | | | | | | | |
| Aldrin | | | | | | | | | |
| Aldrin plus Dieldrin | | | | | | | | | |
| Chlordane | | | | | | | | | |
| Dieldrin | | | | | | | | | |
| DDT | | | | | | | | | |
| Endrin | 0.0002 | 0.0002 | 0.0002 | CBC | CBC | 0.000004 | 0.000004 | 0.000004 | CBC |
| Heptachlor | | | | | | | | | |
| Heptachlor epoxide | | | | | | | | | |
| Lindane | 0.004 | 0.004 | 0.004 | CBC | CBC | 0.00001 | 0.00001 | 0.00001 | CBC |
| Methoxychlor | 0.100 | 0.100 | 0.100 | CBC | CBC | 0.00003 | 0.00003 | 0.00003 | CBC |

KEY: nar = narrative
CBC = case-by-case
a = Class 3C is a case-by-case consideration, except for 13 segments designated in Appendix D where numeric criteria are listed.
b = soluble

# UTAH

## WATER QUALITY STANDARDS

| Parameter | Domestic Source 1A | Domestic Source 1B | Domestic Source 1C | Recreational & Aesthetics 2A | Recreational & Aesthetics 2B | Aquatic & Wildlife[a] 3A | Aquatic & Wildlife[a] 3B | Aquatic & Wildlife[a] 3D | General Standards |
|---|---|---|---|---|---|---|---|---|---|
| Organics (all mg/l) (cont.) | | | | | | | | | |
| Chlorinated pesticides (cont.) | | | | | | | | | |
| Mirex | | | | | | | | | |
| Perthane | | | | | | | | | |
| Toxaphene | 0.005 | 0.005 | 0.005 | CBC | CBC | 0.000005 | 0.000005 | 0.0000005 | CBC |
| Contaminants, trace | | | | | | | | | |
| Herbicides | | | | | | | | | |
| 2, 4 D | 0.100 | 0.100 | 0.100 | CBC | CBC | CBC | CBC | CBC | CBC |
| 2, 4, 5 TP or Silvex | 0.010 | 0.010 | 0.010 | CBC | CBC | CBC | CBC | CBC | CBC |
| Dalapon | | | | | | | | | |
| Dicamba | | | | | | | | | |
| Diquat | | | | | | | | | |
| Dursban | | | | | | | | | |
| Simazine | | | | | | | | | |
| Hydrocarbons | | | | | | | | | |
| Oil and/or grease | | | | | | | | | |
| Organic phosphates and carbamates | | | | | | | | | narrative |
| Orthophosphate pesticides | | | | | | | | | |
| Ciodrin | | | | | | | | | |
| Coumaphos | | | | | | | | | |
| Demeton | | | | | | | | | |
| Diazinon | | | | | | | | | |
| Dichlorvos | | | | | | | | | |
| Endosulfan | | | | | | | | | |
| Fenthion | | | | | | | | | |
| Gunthion | | | | | | | | | |
| Malathion | | | | | | | | | |
| Naled | | | | | | | | | |
| Parathion | | | | | | | | | |
| Phosphaphamidon | | | | | | | | | |
| TEPP | | | | | | | | | |
| Pesticides | | | | | | | | | |
| Petroleum | | | | | | | | | |
| Phenol | CBC | CBC | CBC | CBC | CBC | 0.00001 | 0.00001 | CBC | CBC |
| Phenolics/phenolic compounds | | | | | | | | | |
| Phenols | | | | | | | | | |
| Phthalate esters | | | | | | | | | |
| Polychlorinated biphenyls | | | | | | | | | |
| Biological | | | | | | | | | |
| Actinomycetes colonies, or fungus | | | | | | | | | |
| Algae | | | | | | | | | |
| Benthic macroinvertebrates | | | | | | | | | |
| Chlorophyll a | | | | | | | | | |
| Coliforms, fecal (#/100 ml) | | | | | | | | | |
| Coliforms, fecal (geom. mean #/100 ml) | CBC | CBC | 2000 | 200 | 2000 | CBC | CBC | CBC | CBC |
| Coliforms, fecal (log mean, #/100 ml) | | | | | | | | | |
| Coliforms, total (#/100 ml) | | | | | | | | | |
| Coliforms, total (geom. mean #/100 ml) | 1 | 50 | 5000 | 1000 | 5000 | CBC | CBC | CBC | CBC |
| Coliforms, total (log mean, #/100 ml) | | | | | | | | | |
| Coliforms, total (MPN, #/100 ml) | | | | | | | | | |
| Organisms, pathogenic (#/100 ml) | | | | | | | | | |
| Plankton count | | | | | | | | | |
| *Shistosoma mansoni* (#/100 ml) | | | | | | | | | |
| Radiological (pCi/l) | | | | | | | | | |
| Alpha, dissolved emitters | | | | | | | | | |
| Alpha, excluding uranium and radon | | | | | | | | | |

KEY: nar = narrative
CBC = case-by-case
a = Class 3C is a case-by-case consideration, except for 13 segments designated in Appendix 3 where numeric criteria are listed.

UTAH

WATER QUALITY STANDARDS

| Parameter | Domestic Source | | | Recreational & Aesthetics | | Aquatic & Wildlife[a] | | | General Standards |
|---|---|---|---|---|---|---|---|---|---|
| | 1A | 1B | 1C | 2A | 2B | 3A | 3B | 3D | |
| **Radiological** (pCi/l) (cont.) | | | | | | | | | |
| Alpha, gross | 15 | 15 | 15 | CBC | CBC | 15,nar | 15,nar | 15,nar | 15,nar |
| Beta, excluding Potassium 40 | | | | | | | | | |
| Beta, excluding Strontium 90 | | | | | | | | | |
| Beta, excluding Strontium 90 and alpha emitters | | | | | | | | | |
| Beta, gross | 50 | 50 | 50 | CBC | CBC | 50 | 50 | 50 | 50 |
| Cesium 134 | | | | | | | | | |
| Plutonium 238, 239, 240 | | | | | | | | | |
| Radioactive substances | | | | | | | | | |
| Radionuclides, dissolved | | | | | | | | | |
| Radionuclides, suspended | | | | | | | | | |
| Radium 226 | 5 | 5 | 5 | CBC | CBC | CBC | CBC | CBC | CBC |
| Radium 226 and 339 | | | | | | | | | |
| Radium 226 and 232 | | | | | | | | | |
| Radium 228 | | | | | | | | | |
| Strontium 89 | | | | | | | | | |
| Strontium 90 | 8 | 8 | 8 | CBC | CBC | CBC | CBC | CBC | CBC |
| Thorium 230 and 232 | | | | | | | | | |
| Tritium | 20000 | 20000 | 20000 | 20000 | CBC | CBC | CBC | CBC | CBC |
| Uranium | | | | | | | | | |

a = Class 3C is a case-by-case consideration, except for 13 segments designated in Appendix D where numeric criteria are listed.
b = soluble

# WYOMING

Standards Adopted: 17 July 1979

Standards have not been accepted by USEPA, but no official response has been received

Copies of Current Standards available from:
John F. Wagner
Technical Support Supervisor
Water Quality Division
Department Environmental Quality
Hathaway Office Building
Cheyenne, Wyoming 82002
(307) 777-7781

There is no fee for sending standards
A mailing list for updates is maintained

Responsible Agency: Water Quality Division
Department of Environmental Quality
Hathaway Office Building
Cheyenne, Wyoming 82002
(307) 777-7781

Contacts: John F. Wagner
Technical Support Supervisor
(308) 777-7781

Organization: Standards are divided into 31 sections including authority, definitions, goal, water classes and uses, classification of specific waters, testing procedures and the application of the state's water quality standards.

Classification: There are four classes of water in Wyoming: Class I, no point source degradation; Class II, supporting game fish; Class III, supporting non-game fish; and Class IV, not having potential to support fish. Classification of specific waters is included as part of each state program plan submission.

Mixing Zone Description: The size of the mixing zone shall be determined after consideration of the effect of the discharge on the biological community, water uses, and aesthetic conditions, as well as consideration of the flow conditions and physical nature of the receiving water.

Notable Exceptions: Low flow (7 day, 10 year) exceptions are included in the standards. The adoption and enforcement of the water quality standards is not intended to conflict with the apportionment of water to the state through any of the interstate compacts or court decrees or to interfere with the rights of Wyoming appropriators in the utilization of the water appropriations.

Special Comments: Numerical water quality values are standards.

Antidegradation Policy: The state standards include an antidegradation policy for point sources.

NPDES Permit Authority: Water Quality Division
Department of Environmental Quality
Hathaway Office Building
Cheyenne, Wyoming 82002
(307) 777-7781

Waste Load Allocation: Total daily maximum loading is not part of the state standards.

Revisions: None planned.

Approved by: John F. Wagner
Date: 5 November 1979

## WYOMING

## WATER QUALITY CRITERIA

| Parameter | Class I No Point Source Degradation | Class II Supports Game Fish | Class III Supports Non-Game Fish | Class IV Unable to Support Fish |
|---|---|---|---|---|
| **Physical** | | | | |
| Aesthetic conditions (including clarity, floating materials, foam, scum, sediment, garbage, sewage, slicks, and/or sludge) | narrative | narrative | narrative | narrative |
| Color (units) | narrative | narrative | narrative | |
| Conductivity (micromhos/cm) | | | | |
| Gases, dissolved | narrative | narrative | narrative | narrative |
| Odor, threshold (no.) | narrative | narrative | narrative | |
| Oxygen, dissolved (mg/l) | 6,narrative | 6,narrative | 5,narrative | |
| pH | 6.5-9.0,narrative | 6.5-9.0,narrative | 6.5-9.0,narrative | 6.5-9.0,narrative |
| Solids, settleable (ml/l) | narrative | narrative | narrative | narrative |
| Solids, total dissolved (mg/l) | | | | |
| Solids, total suspended (mg/l) | | | | |
| Taste | narrative | narrative | narrative | |
| Temperature (°C) | narrative | narrative | narrative | narrative |
| Temperature (°F) | | | | |
| Temperature, maximum delta T (°C) | | | | |
| Temperature, maximum delta T (°F) | | | | |
| Transparency | | | | |
| Turbidity (FTU) | | | | |
| Turbidity (JTU) | | | | |
| Turbidity (NTU) | 10,narrative | 10,narrative | 15,narrative | |
| Turbidity (Std units) | | | | |
| Turbidity (TU) | | | | |
| **Inorganic** | | | | |
| Acidity (mg/l-$CaCO_3$) | | | | |
| Alkalinity (mg/l-$CaCO_3$) | | | | |
| Ammonia (mg/l-N) | 0.02,narrative | 0.02,narrative | 0.02,narrative | |
| Ammonia, undissociated (mg/l-N) | | | | |
| Bicarbonate (mg/l-$CaCO_3$) | | | | |
| Boron (mg/l) | | | | |
| Boron, soluble (mg/l) | | | | |
| Bromates (mg/l) | | | | |
| Bromine (mg/l) | | | | |
| Calcium (mg/l) | | | | |
| Carbonates (mg/l-$CaCO_3$) | | | | |
| Chlorides (mg/l) | | | | |
| Chlorine, total residual (mg/l) | | | | |
| Cyanide (mg/l-CN) | | | | |
| Cyanide, ferro- or ferri- (mg/l-$Fe(CN)^6$) | | | | |
| Fluoride (mg/l) | | | | |
| Fluoride, soluble (mg/l) | | | | |
| Hardness (mg/l-$CaCO_3$) | | | | |
| Hydrogen sulfide (mg/l) | | | | |
| Inorganic substances, dissolved (mg/l) | | | | |
| Magnesium (mg/l) | | | | |
| M.B.A.S. (detergents) (mg/l) | | | | |
| Nitrate (mg/l-N) | | | | |
| Nitrate (mg/l-$NO_3$) | | | | |
| Nitrite (mg/l-N) | | | | |
| Nitrate + Nitrite (mg/l-N) | | | | |
| Nitrogen, total (mg/l-N) | | | | |
| Nitrogen, total inorganic (mg/l-N) | | | | |
| Nitrogen/Phosphorus ratio | | | | |
| Nutrients | | | | |
| Phosphate (mg/l-$PO_4$) | | | | |
| Phosphate (mg/l-P) | | | | |
| Phosphorus (mg/l-P) | | | | |
| Salinity (mg/l) | narrative | narrative | narrative | narrative |

WYOMING

WATER QUALITY CRITERIA

| Parameter | Class I No Point Source Degradation | Class II Supports Game Fish | Class III Supports Non-Game Fish | Class IV Unable to Support Fish |
|---|---|---|---|---|
| Inorganic (cont.) | | | | |
| Salts, dissolved (mg/l) | | | | |
| Sodium (mg/l) | | | | |
| Sodium absorption ratio | | | | |
| Sulfate (mg/l) | | | | |
| Sulfide (mg/l) | | | | |
| Uranyl ion (mg/l) | | | | |
| Toxic Metals (all mg/l) | | | | |
| Aluminum | | | | |
| Aluminum, soluble | | | | |
| Antimony | | | | |
| Arsenic | | | | |
| Arsenic, soluble | | | | |
| Barium | | | | |
| Barium, soluble | | | | |
| Beryllium | | | | |
| Cadmium | | | | |
| Chromium | | | | |
| Chromium, soluble | | | | |
| Chromium, hexavalent | | | | |
| Chromium, trivalent | | | | |
| Cobalt | | | | |
| Copper | | | | |
| Copper, soluble | | | | |
| Iron | | | | |
| Iron, soluble | | | | |
| Lead | | | | |
| Lead, soluble | | | | |
| Manganese | | | | |
| Mercury | | | | |
| Molybdenum | | | | |
| Nickel | | | | |
| Selenium | | | | |
| Selenium, soluble | | | | |
| Silver | | | | |
| Silver, soluble | | | | |
| Thallium | | | | |
| Uranium | | | | |
| Vanadium | | | | |
| Zinc | | | | |
| Zinc, soluble | | | | |
| Toxic and/or deleterious substances | narrative | narrative | narrative | narrative |
| Organics (all mg/l) | | | | |
| Benzene hexachloride | | | | |
| Benzidine | 0.0001 | 0.0001 | 0.0001 | |
| Biochemical oxygen demand | | | | |
| Biocides | | | | |
| Carbon chloroform extract | | | | |
| Carbon, total organic | | | | |
| Chemical oxygen demand | | | | |
| Chlorinated pesticides | | | | |
| Aldrin | | | | |
| Aldrin plus Dieldrin | | | | |
| Chlordane | | | | |
| Dieldrin | | | | |
| DDT | | | | |
| Endrin | | | | |
| Heptachlor | | | | |
| Heptachlor epoxide | | | | |
| Lindane | | | | |
| Methoxychlor | | | | |

WYOMING

WATER QUALITY CRITERIA

| Parameter | Class I No Point Source Degradation | Class II Supports Game Fish | Class III Supports Non-Game Fish | Class IV Unable to Support Fish |
|---|---|---|---|---|
| **Organics** (all mg/l) (cont.) | | | | |
| Chlorinated pesticides (cont.) | | | | |
| Mirex | | | | |
| Perthane | | | | |
| Toxaphene | | | | |
| Contaminants, trace | | | | |
| Herbicides | | | | |
| 2, 4 D | | | | |
| 2, 4, 5 TP or Silvex | | | | |
| Dalapon | | | | |
| Dicamba | | | | |
| Diquat | | | | |
| Dursban | | | | |
| Simazine | | | | |
| Hydrocarbons | | | | |
| Oil and/or grease | 10,narrative | 10,narrative | 10,narrative | 10,narrative |
| Organic phosphates and carbamates | | | | |
| Orthophosphate pesticides | | | | |
| Ciodrin | | | | |
| Coumaphos | | | | |
| Demeton | | | | |
| Diazinon | | | | |
| Dichlorvos | | | | |
| Endosulfan | | | | |
| Fenthion | | | | |
| Gunthion | | | | |
| Malathion | | | | |
| Naled | | | | |
| Parathion | | | | |
| Phosphaphamidon | | | | |
| TEPP | | | | |
| Pesticides | | | | |
| Petroleum | | | | |
| Phenol | | | | |
| Phenolics/phenolic compounds | | | | |
| Phenols | | | | |
| Phthalate esters | | | | |
| Polychlorinated biphenyls | | | | |
| **Biological** | | | | |
| Actinomycetes colonies, or fungus | | | | |
| Algae | narrative | narrative | narrative | narrative |
| Benthic macroinvertebrates | | | | |
| Chlorophyll a | | | | |
| Coliforms, fecal (#/100 ml) | narrative | narrative | narrative | narrative |
| Coliforms, fecal (geom. mean #/100 ml) | | | | |
| Coliforms, fecal (log mean, #/100 ml) | | | | |
| Coliforms, total (#/100 ml) | | | | |
| Coliforms, total (geom. mean #/100 ml) | | | | |
| Coliforms, total (log mean, #/100 ml) | | | | |
| Coliforms, total (MPN, #/100 ml) | | | | |
| Organisms, pathogenic (#/100 ml) | | | | |
| Plankton count | | | | |
| *Shistosoma mansoni* (#/100 ml) | | | | |
| **Radiological** (pCi/l) | | | | |
| Alpha, dissolved emitters | | | | |
| Alpha, excluding uranium and radon | | | | |

WATER QUALITY CRITERIA

| Parameter | Class I No Point Source Degradation | Class II Supports Game Fish | Class III Supports Non-Game Fish | Class IV Unable to Support Fish |
|---|---|---|---|---|
| Radiological (pCi/l) (cont.) | | | | |
| Alpha, gross | | | | |
| Beta, excluding Potassium 40 | | | | |
| Beta, excluding Strontium 90 | | | | |
| Beta, excluding Strontium 90 and alpha emitters | | | | |
| Beta, gross | | | | |
| Cesium 134 | | | | |
| Plutonium 238, 239, 240 | | | | |
| Radioactive substances | narrative | narrative | narrative | narrative |
| Radionuclides, dissolved | | | | |
| Radionuclides, suspended | | | | |
| Radium 226 | | | | |
| Radium 226 and 228 | 5 | 5 | 5 | 5 |
| Radium 226 and 232 | | | | |
| Radium 228 | | | | |
| Strontium 89 | | | | |
| Strontium 90 | 8 | 8 | 8 | 8 |
| Thorium 230 and 232 | | | | |
| Tritium | | | | |
| Uranium | | | | |



2400—6/80—1M

## APPENDIX C

### Sampling and Distribution of Things[1]

The relationship of things, the frequency of sampling, and the judgment as to where to sample are all tied together. There is no easy way to separate these facets of program or project design, but I chose to do so in the text because I felt it was more important to have each phase thought about and developed separately. After all, our objective was to design the program or project plan one step at a time. Now, some discussion is needed to tie sampling frequency and distribution patterns together. One thing of which you can always be certain is that a particular discharge, a particular volume of water, a particular constituent concentration, or the presence of a particular type of organism at a given place or time is the result of a series of complex events. That is, there are a number of things that impinge upon the abundance and distribution of things. Here I can only provide some things for you to think about and hopefully to guide you in the design of your program or project.

Let us begin by studying the theoretical distribution patterns in the figure that follows. This is a very simplified portrayal, but with a bit of thought it can become useful in forming our thoughts. Consider sketches A through D. These sketches represent four discrete possibilities of material input to a unidirectional flowing system. Sketch A represents a steady material input and a well-mixed system. During some periods of the year or within some stream or river sections or with some constituents, especially dissolved materials, this type of distribution pattern may occur. But, for a given constituent and for any given stream section, you should not assume this pattern and, more importantly, do not assume this distribution pattern beyond a seasonal period, for in the absence of contrary information, it is not likely to occur. Too often the uniform input and distribution pattern is assumed to exist because of the ease of sampling such a system. That is, one sample collected, almost anywhere, will provide information on the distribution and abundance of things. The scheme of nature is seldom this simple.

Sketch B is an example of a steady input, poorly mixed constituent pattern. For short time periods, this sketch may represent an industrial or domestic effluent or a tributary stream draining a disturbed watershed. That is, the introduced material flows along (hugs) one streambank or the other. Obviously, somewhere along the flow line the material will be distributed from streambank to streambank; the more meandering the stream within its floodplain the more rapid per unit distance or velocity will be the mixing. For any given stream section, you must determine the distribution of the constituent or material of interest, and you should never assume that a steady-input distribution pattern will occur throughout the year or even for much shorter periods.

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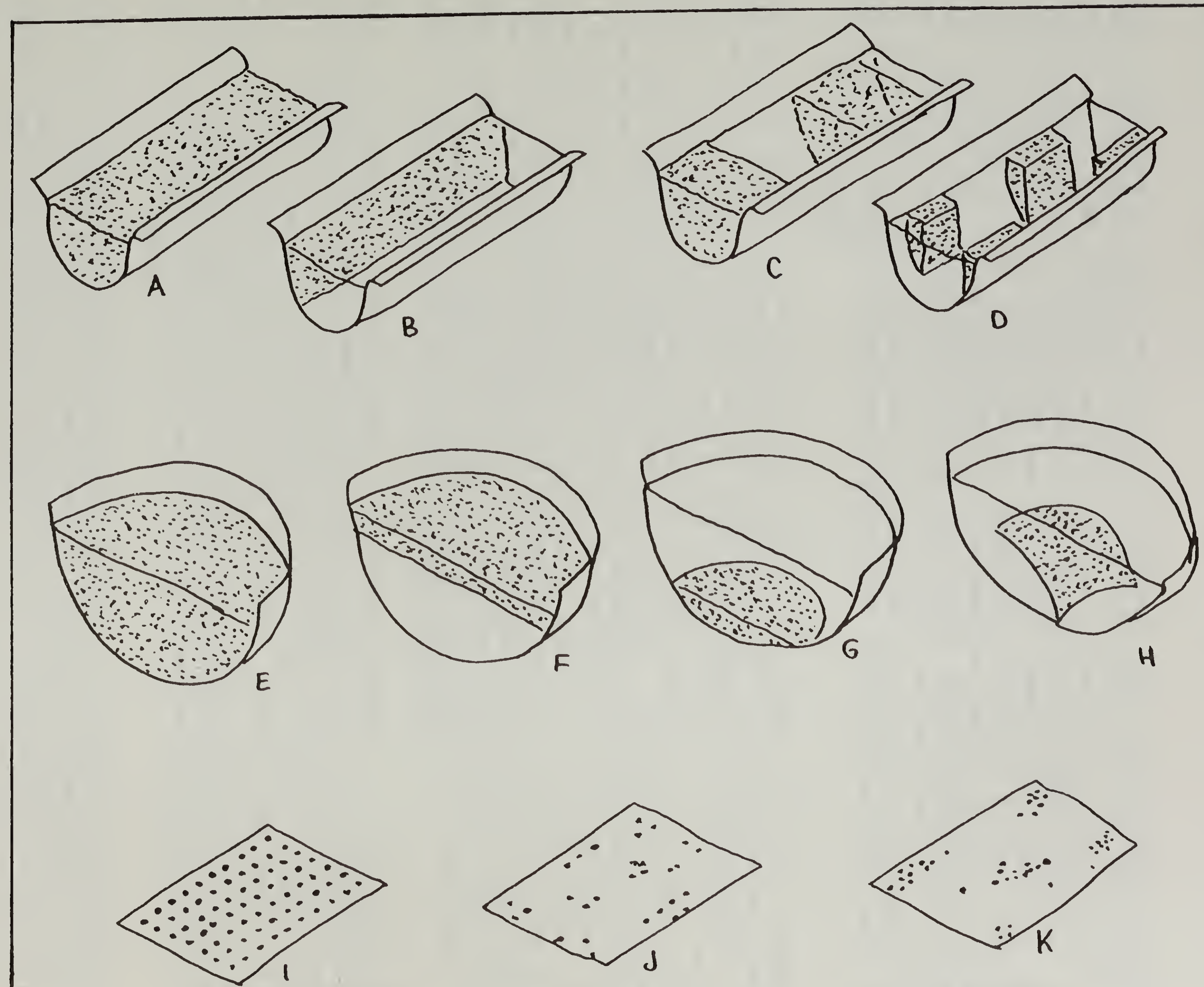
[1] The following discussion is quoted from A Guide to the Design of Data Programs and Interpretive Projects, A Class Handout by Robert C. Averett, USGS Water Resources Division, Central Region, Lakewood, Colorado.

Theoretical
Distribution
Patterns



Man-induced inputs, such as industrial effluents, may vary greatly in quality and quantity depending upon a number of events, such as the manufacturing process, the local discharge regulations, and the seasonal aspects of the manufactured product. The mixing of such material will depend upon its density, whether it is dissolved, and so forth. Domestic effluents may vary in volume and constituent concentration because of the nature of the community; that is, visitor use may be higher at some seasons than at others. A tributary that drains a disturbed watershed may have a much greater constituent input during high flow periods than at any other time. At low flows, the tributary may have little, if any, influence on the receiving stream. Representative sampling of such systems requires a great deal of thought and often some preliminary samples.

Sketch C represents an erratic input, well-mixed system. With this scheme, whatever is put in the system is well mixed but the input pattern is erratic; the material is not released to the receiving stream in a uniform manner. You could easily sample when low constituent concentrations were present, you could sample when high constituent concentrations were present, or you could sample when high constituent concentrations were present. The distribution pattern illustrated by sketch C will require more sampling effort than that illustrated in sketch A, and you also must consider the leading and trailing edges of the constituent material as it flows downstream. That is, the leading edge may be located in the stream center or area of maximum velocity and may extend well in front of the maximum concentration. The trailing edge, depending upon the constituent type, may lag well behind the maximum concentration. Thus, while mixing is complete in that the constituent is found throughout the cross section, there may be a wide variation in concentration.

Sketch D represents a poorly-mixed, erratic-input system. The frequency of sampling must be greatly expanded here if you are to describe the distribution and abundance of things. Some industrial effluents follow this pattern and often, runoff from summer thundershowers may follow or result in this type of erratic-input, poorly-mixed distribution pattern. Whatever the cause for the distribution pattern shown by sketch D, you must give a great deal of thought to your sampling scheme. If your frequency is inadequate, you will have no idea as to how the system functions or the distribution and abundance of materials in the system.

Sketches E through H represent impounded systems. The water in such systems will have moved vertically and horizontally (upstream, downstream, and cross current) before it leaves the impounded section of the system. You should realize these possibilities and be aware of the involved changes that may occur.

Sketch E represents a well-mixed, impounded system. Lakes in the temperate regions of North America often exhibit such well-mixed homogeneous dissolved constituent profiles from top to bottom during the spring after ice-melt and in the autumn after thermal stratification; but the well mixed distribution pattern sketched by E is often short-lived in such systems and disappears after thermal stratification occurs. In shallow points that do not thermally stratify or nonthermally stratified, wind-mixed systems in the southern areas of North America, the distribution pattern illustrated by sketch E may be long-lived; but in the absence of good solid information, do not count on

such a distribution pattern to be widespread in either time or space in most impounded systems.

Sketch F illustrates a system where the greatest concentration of constituents is near the surface. This distribution pattern corresponds to the erratic-input but poorly-mixed system of "B" above. We often find phytoplankton in an enriched lake or reservoir to follow this distribution pattern for short periods in the summer. That is, algal mats may occur on the surface. Recent evidence indicates that the distribution of viable phytoplankton cells in unenriched lakes and reservoirs may not be restricted to the lighted (euphotic) zone but that the cells may be distributed throughout the depth of the lake. In a thermally stratified lake where wind mixing of the water is restricted to the surface or epilimnion, there, and only there, a homogenous distribution of materials may occur. Moreover, during high algal production (bloom) periods, the greatest concentration of phytoplankton and, hence, plant nutrient uptake and release often will be found in the surface water.

Sketch G represents a system in which the greatest distribution of things is near the bottom. Now we could easily relate "G" to organisms that live on the bottom of lakes and reservoirs, but the distribution is equally applicable to sinking phytoplankton cells as well as some chemical constituents that are found in their highest concentrations in the water that lies just above the lake bottom, the so-called hydrosol. If the lake or reservoir is thermally stratified and oxygen depletion occurs in the hypolimnion, then you can expect higher concentrations of manganese, ferrous iron, phosphorus, and so-forth to occur in the anoxic water. The presence of these constituents in the hypolimnion does not, however, mean that they are available for phytoplankton use in the waters of the epilimnion. As mentioned above, we could relate benthic organisms, including periphyton, in shallow systems to the distribution pattern of sketch "G"; but we will have more to say about this later.

Sketch "H" shows a relatively low-constituent distribution pattern at the surface followed by a subsurface maximum at some depth just below the lake surface. The abundance of the constituents drops off rapidly at greater depth. In effect, this distribution pattern is an extension of sketch "G" and illustrates the typical phytoplankton abundance curve well known to lake limnologists. It also approximates the primary production curve of phytoplankton in lakes. At the surface, excessive light results in the inhibition of the photosynthetic process. At some depth below the lake or reservoir, surface optimum light conditions for photosynthesis occurs; but at greater depths, light restriction takes place and photosynthesis decreases, until at the compensation point photosynthesis and respiration are equal and primary production is zero. Now it is possible to find the greatest phytoplankton concentrations at the surface and still find the greatest primary production or photosynthetic activity at greater depths. This event is, of course, related to the photosynthetic efficiency of individual phytoplankton cells.

The enrichment status of a lake or reservoir can be very important from the standpoint of deciding what to sample and where to sample it. Dissolved oxygen depletion often takes place in the hypolimnion (deep water zone) of thermally stratified enriched lakes. When this occurs, a host of events, including dissolution of many so called insoluble constituents and the death or movement

of aquatic organisms requiring free or dissolved oxygen takes place. From the standpoint of organism well-being, or life vs death, do not confuse low dissolved oxygen concentrations with zero dissolved oxygen concentrations. Many aquatic animals can live under conditions of low dissolved oxygen, but only bacteria can live under anoxic conditions. Thus, the dissolved oxygen concentration is an important guide for sample site selection and the frequency of sample collection.

Sketches I, J, and K represent the distribution patterns of benthic materials and organisms but could be extended, with some thought, to materials and organisms in the water column as well. These sketches represent distribution patterns that we can describe from a statistical modeling standpoint. We will view them from the standpoint of things on a plane, but the principles involved will be applicable from a three-dimensional profile as well.

Sketch I represents a uniform distribution pattern. While few things are uniformly distributed in nature, a uniform distribution is possible over short time periods or within small areas. For example, Elliott (1971) reported that the territorial behavior of some lake and stream bottom organisms resulted in a uniform distribution or, at least, a distribution that could be approximated by the uniform pattern. Very small suspended particles such as clay and solids in solution also follow a uniform distribution pattern, at least, in a restricted area or over a short time period.

The uniform distribution pattern greatly simplifies any sampling program, for only a single sampling site need be located in a given section. But, as mentioned before, the uniform distribution is often not a reality in nature and should never be assumed. From the standpoint of a statistical model, the uniform distribution is most accurately described by the positive binomial model, or where the variance is less than the mean ($s^2<\bar{x}$).

Sketch "J" represents a random distribution. This distribution pattern is represented by the Poisson model, where the variance is equal to the mean ($s^2=\bar{x}$). The random distribution simply means that there is an equal chance that something can occupy any place in an area being sampled. That is, the presence of something at one place in time and space does not interfere or depend upon the presence of something else nearby. There is, in fact, no pattern to a random distribution.

We often assume that things are randomly distributed in nature. This assumption is often based on the use of a random sampling scheme and not on a random distribution. A random sampling scheme is designed so that every item in the population being sampled has an equal chance of being selected. It does not mean or imply that the things being sampled are randomly distributed. In fact, few things in nature are randomly distributed; in almost all cases, things in nature influence and are influenced by things nearby. As mentioned several times before, the more we learn about something, the more we discover how it is related to something else.

Sketch "K" represents a clumped, patchy, or contagious distribution. Almost all living things, and many nonliving things, in nature follow the clumped distribution. The distribution is best approximated by the negative binomial model where the variance is greater than the mean ($s^2>\bar{x}$). Now the clumps

themselves may be randomly distributed, or nearly so, but the actual organisms or constituents are in a clumped fashion because of relations of one to the other--that is a dependence that one has to the other. In fact, the clumped distribution pattern is often called the contagious distribution because in plotting areas of infection or contagious diseases in population centers, the areas of infection have a clumped or patchy distribution pattern. The sampling of constituents having a clumped distribution requires a knowledge of the behaviour of the constituents, controls on the constitutents, and constituent-constituent relations if the maximum amount of information is to be obtained with the least amount of sampling effort.

The discussion presented here has centered around possible, yet theoretical distribution patterns. You should study these patterns thoroughly, for regardless of their theoretical implication, they can provide considerable insight to the distribution of things in the system you are studying. As a final aid as well as a conclusion to our distribution section, I have listed some types and groups of constituents that we commonly sample in our programs, their sources, and their distribution patterns. The discussion is simple and you should be able to add a great deal more than I have provided.

## Water Temperature

The temperature of the water is of great importance in many hydrological events. Evaporation rates, the solubility to many constituents, and the settling rates of suspended particles are all temperature dependent. Temperature is an important controlling factor for all life processes such as respiration, photosynthesis, growth, and so-forth. Moreover, the water temperature also can be a lethal factor, for all organisms have a temperature range outside of which they cannot survive.

Water temperature may vary greatly at a single point in a stream throughout the year. But seasonal as well as daily (diel) variations may be pronounced. Thermisters placed in a stream and attached to a recorder, say at a gaging station, may provide useful water temperature information at that point over a long time period. But while useful, such measurements must be used with caution as the water temperature may vary or change greatly immediately downstream from the thermister because of surface or groundwater inflow. Moreover, the water temperature just above the thermister may be warmed or cooled by local inflow resulting in a reduction in the transfer value of the temperature data to a larger area. What this means is that the location of the temperature recording probe for purposes of obtaining a real measurement of stream temperature must be done with care. Before accepting a site as satisfactory for a thermal record, a temperature reconnaissance study is needed. The reconnaissance can be easily made with minimum-maximum thermometers placed in strategic places in the stream, and instantaneous temperature measurements can be made with a pocket thermometer. A low flow water-temperature reconnaissance is often sufficient, but you should know something about the discharge pattern of nearby tributaries. That is, the temperature differential between these tributaries and the mainstream and the expected high to low flow ratio of the tributary to the mainstream should be known. The point is that well-shaded tributaries that drain high elevations may be considerably cooler than the mainstream into which they flow and may have, depending upon their volume, a significant influence on the water

temperature of the mainstem flow. In addition, cooler tributary water may flow along the shoreline of the mainstem for some distance downstream resulting in a temperature difference across the mainstem. Thus, the measurement of water temperature along one bank of the mainstem would not be representative.

The influence of man usually results in higher water temperatures. For example, water from a cooling tower is usually considerably warmer than the receiving stream. This heated water may be released along the streambank and the effect similar to the cooler tributary water discussed earlier, except that the inflowing water has a higher temperature than the mainstem. Heated water that is released through a diffuser pipe placed across a stream may cause an abrupt and immediate water temperature change at the pipe.

We often assume that under ice cover, the water is homothermous; that is, just above freezing in the instance of flowing water. But warmer water from seepage or springs may result in a locally increased water temperature. Such areas result in micro-habitats where particular constituents may be found in higher-than-usual concentrations. Influences such as this explain why the clumped or clustered distribution pattern of things is common in nature.

If a reservoir dam has a multiple penstock and the reservoir thermally stratifies in the summer, the water temperature in the reservoir outlet can be somewhat controlled. In the summer, cooler water can be released from the reservoir hypolimnion resulting in a downstream water temperature lower than that which would have occurred were the reservoir not there. If warmer water is needed, such as for some cold-sensitive crops, water can be taken from the top or epilimnion of the reservoir. The point to remember is that unless you know the reservoir temperature profile and the planned depth of release pattern, you must make rather frequent temperature measurements in order to define the temperature pattern of the outflowing stream system. But, if you know the reservoir temperature pattern and the planned depths of release, you can reduce temperature measurements greatly because you can easily model the temperature regime. This literature is sparce on studies of water temperature in streams and voluminous on water temperature studies in lakes. A good place to start reading on water temperature and its measurements is Stevens et al. (1975).

## Discharge

We are all familiar with stream discharge and its measurement. For many stream systems, we have an extensive discharge record available and the expected flow regime of the stream for a given time can be easily determined. However, often we must undertake studies in remote areas where discharge records are lacking or only where an incomplete record is available. In many instances, a discharge record is needed but there is no way to synthesize it. The only feasible way is to start making discharge measurements and obtain some information and a discharge-stage relation. The result of this activity will, of course, not result in a long-term discharge record and, in many instances, your study may be completed before any kind of a predictive flow regime can be determined from the discharge measurements.

Nevertheless, you will have to make do with the data you have. It is because of these types of short-term data problems that your experimental design (planning report) must be carefully thought out, carefully written, and carefully documented. When you are sampling constituents that are discharge related, you should carefully delineate the discharge at the time of sampling and record in your report the discharge range experienced during your study period. If you should carry out your study during a dry cycle, your reader should be aware of this at once. The extrapolation of your findings to a wet cycle may not be a sound procedure. What I am saying is that a long-term discharge record is often not needed to carry out a useful research project. You do need to clearly describe the discharge at the time your study was made and when your samples were collected.

That is about all I have to say about discharge. The frequency of measurement and how elaborate and complete you wish the discharge record to be will depend upon your data needs and, or course, the period of available record. Remember, however, that discharge is an important component of most studies and must be considered in your program or project plan.

## Fluvial Sediment

It has been mentioned several times throughout the text that suspended (fluvial) sediments are an important transporting mechanism for many sorbed materials especially organic material and trace elements. Fluvial sediment also is an obviously important parameter to measure from the standpoint of channel morphology changes and the filling of reservoirs.

The amount of sediment in a stream cross-section moving past a point at any time may be highly variable. Moreover, the vertical distribution of sediment may vary greatly depending upon the depth, velocity of the stream section, and upon the size of the sediment (coarse or fine). For an excellent discussion of fluvial sediment concepts and measurements, see Guy (1970) and Guy and Norman (1970). Figure L, page 3, in Guy and Norman, is a particularly useful illustration of sediment concentration, stream velocity, and the possible depth that can be sampled with existing equipment. Fortunately, the USGS Water Resources Division is renowned in the measurement of fluvial sediment, equipment, and expertise. But, anyone planning to include sediment measurements in their study should read the above two publications. Fluvial sediment should always be sampled with recognized U.S. Geological Survey samplers.

Sampling sites for fluvial sediment should be selected so that samples can be collected during high discharges; the period of maximum sediment transport. This means that access to the sampling site must be given careful consideration. Wherever possible, avoid sampling near bridge piers of other objects that constrict or alter streamflow patterns. Such objects disrupt the pattern of sediment movement and result in samples of higher than normal sediment concentrations.

While most "natural" high sediment concentrations take place at high flows and during runoff periods, man-induced sediment concentrations may occur at any time of the year if the stream velocity is sufficient to transport the material. Thus, land disturbance in an area of study may result in increased

sediment concentrations at a time when the stream would not carry a signifcant sediment load. It is important, therefore, to have a knowledge of land use practices in the study area. Aerial photographs are of great value for this purpose. If the photography is of high enough resolution, areas of erosion and sediment deposition also may be determined by aerial photographs.

As mentioned before, the publications by Guy (1970) and Guy and Norman (1970) should be read prior to the design of a study involving fluvial sediment measurements. For an excellent publication on sediment, channel morphology, and bed material, see Emmett (1976).

## Major Dissolved Constituents

The major dissolved constitutents include the cations and anions that represent the bulk of dissolved solids in water. They are relatively soluble and are of immense importance from a water-quality standpoint. We often assume that a dilution controlled dissolved solids-discharge regression can easily be developed for a given stream or stream section; that is, the concentration of the dissolved solids will decrease with increasing discharge, but you should not accept the assumption unless you know that the stream or stream section is free from man-caused inputs. Irrigation return water which has drained salt-laden soils can disrupt the expected dilution controlled relations between dissolved solids and discharge. Also, do not assume that the discharge-dissolved solids regression for tributaries will be the same as the mainstem. The two systems may drain entirely different watersheds including not only geological but also vegetative types.

We often use the surrogate measurement of specific conductance to estimate the dissolved solids concentration in water. The specific conductance measurement is simple and can be done quickly in the field. In many waters, the ratio of dissolved solids to specific conductance is about 0.65. For planning purposes, this assumption may be used without further consideration. But beware of the 0.65 coefficient as a general rule. If you are to relate dissolved solids to specific conductance in a system where information is lacking, you simply must make some measurements and obtain the specific conductance-dissolved solids relation for the system you are studying and you must consider the season of the year. In some systems, high concentrations of silicon, as silicon dioxide, or as the hydrated from $H_4SiO_4$ may be present resulting in a dissolved solids-specific conductance ration quite different than 0.65. The reason, of course, is that the silicon is nonionic and is not measured as a part of the specific conductance but is measured as a part of the dissolved solids concentration. Errors of field measurement also may account for considerable variations between the dissolved solids-specific conductance ratio. An analysis of some central Region data showed, for example, a large discrepancy when field and laboratory specific conductance data were compared to calculated and laboratory determined dissolved solids values. The careful calibration of field instruments is essential to collecting data that helps us understand hydrological systems. For a further discussion on major dissolved constituents, dissolved solids, and specific conductance, see Hem (1970).

## Pesticides

Pesticides, a collective term for substances used to kill unwanted plants and animals, are often measured as a part of our hydrological studies. Only recently have we learned much about the distribution of pesticides in aquatic systems. A few years back most of our measurements were restricted to the water phase. Concentrations on bed and suspended sediments were virtually ignored. We now know that most pesticides are strongly sorbed to organic and inorganic sediment particles. Because of their relatively insolubility, most pesticides are found in very low solution concentrations. Hence, the measurement of pesticides in the water phase of a hydrological system provides information on only a part, in fact a small part, of the total amount that might be present.

The important point here is that if you wish to obtain information on the types and concentrations of pesticides in a system, the suspended sediment bed material as well as the water must be analyzed. The highest concentration and the most kinds of pesticides often will be found in areas of sediment deposition. You can collect these samples at low flow.

If a part of your study objective is to determine pesticide transport in a hydrological system, you will want to include suspended sediment in your sampling scheme. Now most sediments are in suspension during a relatively short time period; that is during high flows. Pesticides applied to farm crops thus would be expected to move into streams with the first heavy runoff and be transported downstream at this time. However, there may be movement from crop and filed lands into low flowing streams during periods of crop irrigation especially if flood irrigation practices are used. Consequently, the measurement of pesticide transport requires not only a knowledge of the flow regime of the system being sampled but also sources of input water to the system.

As mentioned earlier, not all pesticide sampling need be done at high flows. In fact, at low flows you can make a rather good reconnaissance of the presence of pesticides in a stream section by collecting and analyzing samples of settled material from the streambed. Collect in areas where the finest sediments have been deposited for there the greatest concentrations of pesticides will be found. While you cannot obtain a quantitative idea as to the amount of pesticides having been transported by the stream with this sampling technique, you can certainly obtain an idea of the types of pesticides present. Sometimes this is all the information you need.

There has been much written on pesticides in recent years. From a sampling standpoint, the Techniques of Water Resource Investigation publication by Goerlitz and Brown (1972) is a good place to begin. Personnel at the USGS Denver Central Laboratory are another excellent source on pesticide sampling, analysis, and literature.

## Trace Elements

Trace elements have a number of distribution characteristics similar to pesticides. That is, many trace elements are relatively insoluble in water and

hence are found in low concentrations and are readily sorbed on suspended and settled materials, both organic and inorganic. Consequently, if your study goal is to determine the distribution and abundance of trace elements in a system, you must plan to sample at periods of sediment transport and sample the suspended as well as the bed sediments. You may sample for trace elements in the bed sediments at low flow periods, collecting samples in areas where the finest materials have been deposited. If at all possible, you also should determine the size frequency of the bed sediments.

Many trace elements readily became soluble in anaerobic systems. This means that in thermally stratified lakes where the deeper water becomes anoxic the concentrations of trace metals are likely to be higher than in the overlying oxygenated water. This attribute could be of great significance in the design of a sampling program and, of course, ties directly into the stratified random sampling scheme.

Remember that the term trace element is a broad category and that there is much overlap between such categories as trace elements, major constituents, and plant nutrients. You must have a knowledge of each individual element and its aqueous behaviour in order to make intelligent judgments about its distribution and abundance. Two texts that are helpful in this regard are Hem (1970) and Stumm and Morgan (1970).

A final note is due here. We often read of studies designed, in part, to determine the distribution of "toxic" trace metals. Now trace metals, when found at high enough concentrations, certainly can be toxic. But, they also can be toxic when they are absent from the system as most trace elements and metals are essential for life. The term "toxic" is a misnomer when applied to the individual element or compound. It is a true term ony when applied to the concentration of the element or compound.

## pH

The pH of water is an easy and common measurement. So easy in fact that we sometimes measure it without good reason. This statement is not to detract from the importance of pH but to emphasize that pH measurements, like all constituents considered in your project plan, should be there for a reason; it should pull its weight in the traces.

In well buffered waters or very large systems, the pH will not vary greatly in the absence of man-induced inputs of mineral acids and bases. But in smaller systems that are poorly buffered, daily and seasonal changes in pH may occur in the absence of man-induced inputs of material. You can easily determine the relative buffer capacity of the water you are studying by making a series of alkalinity determinations.

Changes in pH can be brought about by the introduction of acids and bases to the system or by excessive respiration (primarily by bacteria and plants) and by plant photosynthesis. Both photosynthesis and respiration influence the carbon dioxide regime of the system. The pH will be relatively low in

anaerobic water where respiration has removed the dissolved oxygen from the water and the carbon dioxide concentration is high. In contrast, the pH will increase under conditions of high photosynthesis. Diel changes in pH, much like that described for dissolved oxygen, may occur in streams that receive organic material. Even leaves falling into a stream may result in a shift in the pH through bacterial respiration.

The pH of water can have a strong influence on the distribution and abundance of things. Many trace elements are insoluble or nearly so at normal pH values. Only when the pH drops to near 4 or so does the solubility of these elements increase significantly. Moreover, the pH governs, to a great extent, the potential toxicity of many compounds to aquatic life.

Most water-quality multiparameter units include a pH probe and readout. Thus, it is possible to obtain pH measurements under most circumstances and over long time periods with relative ease.

In the design of your study, be certain that you consider cross-section and depth measurements of pH. Do not assume a uniform pH in areas where effluents or tributaries enter the mainstream. In lakes, the pH should be measured at the same frequency and at the same depths as dissolved oxygen.

## Dissolved Oxygen

The solubility of dissolved oxygen is highly dependent upon the temperature of the water. When you find high water temperatures, you will, other things equal, find lower dissolved oxygen concentrations. In contrast, lower water temperatures result in higher dissolved oxygen concentrations. When you measure the dissolved oxygen concentration, you should always determine and record the water temperature as well.

Dissolved oxygen in streams will vary seasonally as well as over a 24-hour (diel) period. If the stream receives organic waste, diel dissolved oxygen concentrations may vary greatly in the spring and summer when plant production and bacterial decomposition is high. The diel dissolved oxygen concentration may range from supersaturated (concentrations well above that expected at the ambient temperature and pressure) in late afternoon to undersaturation (below the expected concentrations to zero) during the hours of darkness.

The dissolved oxygen concentration may have a profound influence on the distribution and abundance of many things, such as trace elements, plant nutrients, and aquatic animals. Thus, when the dissolved oxygen concentration varies greatly or is excessively high or low, look for changes in the distribution and abundance of things to occur and adjust your sampling program accordingly. Remember too that man-caused inputs are not the only things that cause wide fluctuations in dissolved oxygen in streams or lakes. Leaves from streamside trees and shrubs may place enough organic matter in the stream to cause a wide diel fluctuation in dissolved oxygen in the autumn. Usually, however, conditions are not as severe in the autumn because the water temperature is low and bacterial decomposition of organic material proceeds at a slower rate.

Fortunately, we now have meters and probes which permit the rapid measurement of dissolved oxygen. Reconnaissance studies of a stream section, or even an entire stream system, can be made quickly. The meters also can be installed to recorders and at least short-term continuous dissolved oxygen records can be obtained.

Pools in streams may thermally stratify in the summer and the dissolved oxygen in the bottom of the pool may be higher or lower than at the surface. The dissolved oxygen in water flowing over stream riffles tends to be uniform because the agitating effect results in the gas returning to equilibrium saturation at the given temperature and pressure.

In lakes and reservoirs, the measurement of dissolved oxygen as a function of depth is essential to understanding a number of processes as well as the distribution and abundance of many constituents. The only way to determine the oxygen regime of lakes or reservoirs is by frequent measurement. Fortunately, meter and probe systems are available for use in deep lakes, but do not measure only in the deepest water or at single stations in the lake center. Consider also the dissolved oxygen concentrations in shallow areas, especially the littoral zone and in the arms of reservoirs. Where cold water tributaries enter the lake, the dissolved oxygen concentration may be higher than in other parts of the lake and a clustering of some constituents, including animals, may take place. In enriched thermally-stratified lakes, the bottom water (hypolimnion) may be devoid of oxygen in mid to late summer regaining dissolved oxygen saturation only after the autumn overrun. This anoxic period might have a significant influence on the distribution and abundance of things you are measuring as a part of your study.

All limnology books have a section or two on dissolved oxygen. Hutchinson (1975) discusses the gas in lakes. Reid and Wood (1976) discuss dissolved oxygen in lakes, stream, and estuaries.

## Phytoplankton and Periphyton

Phytoplankton are free-floating algal cells whereas periphyton are algal cells attached to solid substrates.

Phytoplankton has been discussed in several places in the text. From a distribution standpoint, it is important to remember that there may be rapid production or "bloom" periods if the nutrient concentration in the system is sufficiently high. A particular bloom will often have one or several dominant species, but as the spring and summer progresses and other blooms occur, there may be a shift in the dominant phytoplankton types. In enriched lakes, there is often a succession beginning with diatoms and green algae in the spring and summer followed by excessive production of blue-green algal types in the summer. Excessive production of blue-green algae with attendant "scum" on the water surface is an indication of excessive enrichment of the system.

The depth as well as horizontal distribution of algae in a lake may vary greatly and, as mentioned, under the case study example on lakes sampling may have to be carried out quite frequently. With a reconnaissance study, you

often can find a single convenient spot for sampling and obtain some insight to the distribution abundance and algal species composition in a lake. The vertical distribution of phytoplankton also may be quite variable but, for reconnaissance purposes, you can usually find a centrally located site and make some measurements before, during, and after a bloom.

If your study objective is to define in some detail the horizontal and vertical distribution and abundance of phytoplankton in a lake, then you will need to establish several stations; some in the pattern of the prevailing wind and some protected from the wind. You will need to sample frequently, at least monthly in the spring and probably biweekly or more often in the summer if the system is enriched.

In a river, the number of phytoplankton cells passing a point may vary greatly with time, even within the period of an hour. Most river phytoplankton is dislodged periphyton and the number of cells released from a substrate depends upon the stream velocity, photosynthetic production, scouring by sediment, and so-forth. A study by Britton and Averett (1976) in the Sacramento River, California, revealed that hourly samples were needed to describe, with any degree of accuracy, the phytoplankton concentration passing a point on the river; but seasonal composition changes and long-term trends often can be determined with monthly or bi-monthly samples.

Periphyton are most easily sampled by placing artificial substrates (plastic strips, glass slides, and so-forth) in streams or lakes and letting the periphyton colonize the strips. (See Slack et al. 1973, and Greeson et al. 1977, for a description of artificial substrates for periphyton and their placement.) The length of time that an artificial stubstrate should be placed in the stream for periphyton colonization depends upon the clarity of the water, the amount of sunlight, the concentration of nutrients in the water, and the water temperature. Studies by Britton and Ferreira (oral communication) have revealed that two weeks is often sufficient.

Periphyton abundance will be most common in the spring and summer in temperate zones. Low winter temperatures often arrest growth and production. In more tropical zones, periphyton production may take place throughout the year.

## Benthic Invertebrates

The distribution pattern of benthic invertebrates was mentioned earlier when we discussed the patchy or clumped distribution. You may expect to find benthic invertebrates in any type of lake or stream bottom material. The rubble in stream riffles, that is gravel and rocks up to fist size, will usually have the greatest variety of benthic organisms. The greatest numbers of organisms also may occur in this type of habitat but most likely will be found in areas of organic material and clay deposits in pools. While the organic substrate habitat type will often have the highest number of organisms, it will often have the least number of species; that is the lowest diversity. Sand or small unconsolidated gravel will usually have the least number of benthic organisms because of a lack of food supply and because this type of substrate is often unstable.

In lakes or ponds, the highest number of benthic organisms and benthic organism types will often be found near the margin where light penetrates to the bottom and photosynthesis occurs. Such areas usually remain saturated or near saturated with dissolved oxygen and food is usually abundant.

Many benthic invertebrates, especially the larvae and nymphs of aquatic insects, emerge or leave the aquatic system when they become sexually mature. When terrestrial, they mate and the female lays her eggs over or in the water and the cycle begins anew. What this means is that both the numbers and types of organisms in the stream or lake may vary greatly from time to time. Your sampling plan or at least your data analysis must take the adult emergence-egg laying event into consideration. Usually, however, there will be an overlap between generations and some members of each species will be in the stream or lake at any given time. But, from the standpoint of organism numbers, the variability may be high. It is for this reason that most benthic invertebrate studies are qualitative rather than quantitative although statistical techniques for quantitative studies are available.

Benthic invertebrate sampling can be time-consuming and data analysis is expensive. Consequently, you will want to select your sampling sites and your frequency of sampling carefully. In streams, you can often restrict sampling to riffle areas, but if you expect organic loading, you may need to sample in pools or areas of material deposition as well. Seasonal sampling is often adequate and under many circumstances sampling can be suspended in the winter. In lakes, sampling can often be restricted to near shore areas but avoid areas around boat docks where the propeller wash often disrupts the bottom material of the lake and results in an unstable substrate.

In lakes that become thermally stratified and anoxic in the hypolimnion, benthic invertebrates may be useful indicators of the fitness of the deep water environment. Under low dissolved oxygen conditions, a limited but rather distinct benthic fauna often will be found.

There are a number of excellent references on sampling benthic organisms. An excellent place to start is Slack et al. (1973), Greeson et al. (1976), or Elliott (1971).

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